OPERATING AND SERVICE AND MANUAL

TREMETRICS
MODEL 900A
VLF/LF RECEIVER

TREMETRICS

Tracor Model 900A VLF/LF Receiver

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G. Kerber
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SERVICE MANUAL

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TREMETRICS
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MSK OPTION ADDENDUM

The Model 900 Receiver is modified for MSK reception by addition of a circuit card shown in schematic diagram Figure 900-ADD-1 . On the large circuit card C409 is removed and U402 pin 5 supplies the i-f input to the MSK card, while R444 receives the i-f output from the MSK card. R417 and R420 on the original circuit card are changed to 100K.

From time to time beginning in 1976 the Navy VLF transmitters may convert to MSK transmission.

For MSK reception place the MSK on/off switch at on. The proper setting of the Baud rate will be as follows:

17.8	Cutler	200
21.4	Annapolis	200
23.4	Laulualei	200
22.3	Australia	200
18.6	Jim Creek	100
24.0	Balboa	200

Tuning using the front panel tuning switches is the same as for non-MSK reception (i.e. NAA Cutler 17.8 is UDUU DDDU).

The indicator light will be active with MSK off even when MSK is transmitting. Observation of tracking action with MSK ON and OFF will be about the only method to determine when switchover to MSK has occurred.

Interpretation of frequency offset (described on pages 6 through 16 for non-MSK reception) is modified as follows. For 200 Baud MSK the received signal is 50 Hz below the nominal carrier. Thus from NSS, Cutler Maine, for example, the frequency is 17.75 KHz instead of 17.8 KHz. Action of the MSK card doubles the phase shift, so the results is the same as for twice the received frequency, or in the present example as though 2 X 17.75 or 35.5 KHz

were received. Thus if the result of figure 5, page 13 were achieved using MSK reception from NAA, the conversion from centicycles to microseconds would be 0.28 (using figure 1, page 8, for 35.5 KHz). The change of 2943 CEC (page 16) would be multiplied by 0.28 to give

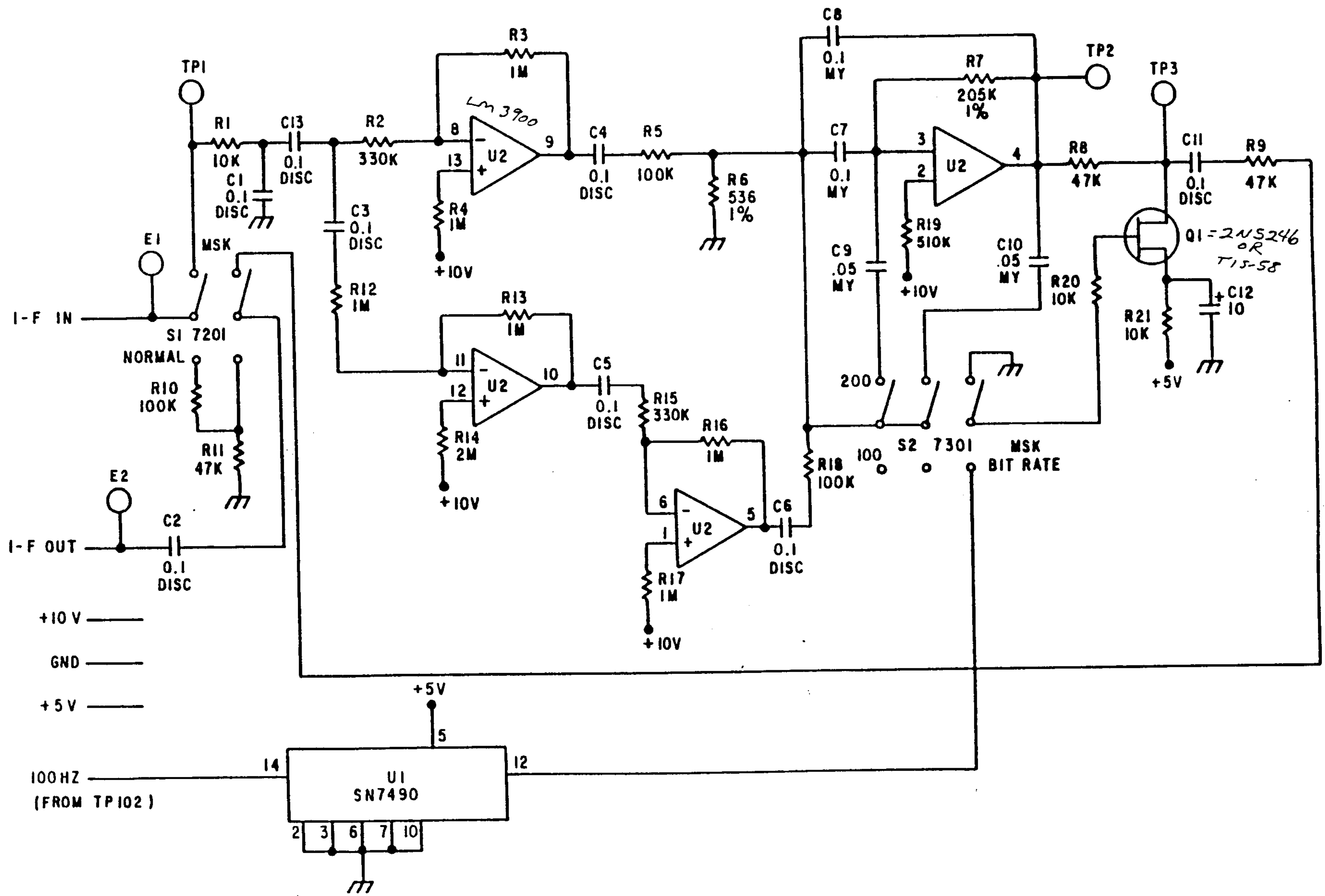
$$-2943 \text{ CEC X } 0.28 \ \frac{\text{microseconds}}{\text{CEC}} = -828 \ \mu\text{s}$$

The corresponding frequency offset is 0.95×10^{-8}.

For 100 Baud the frequency is low by 25 Hz. Thus Jim Creek would be at 18.575 KHz. Again multiply by 2 to get 37.15 KHz.

A simpler procedure which is sufficiently accurate for most purposes is to make the calculation just as though non-MSK transmission were in use and then divide the result by 2.

U2 = LM3900



MSK OPTION SCHEMATIC DIAGRAM
FIGURE 900 ADD I

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ADDENDUM
900A MANUAL

Listed below are currently available (1986) VLF/LF stations with stabilized carrier frequencies suitable for reception using the 900A receiver.

STATION	FREQUENCY	LOCATION	TRANSMISSION	RADIATED POWER
Omega	12.1 KHz	Norway	CW Pulse	10 KW
Omega	12.0 KHz	Liberia	CW Pulse	10 KW
Omega	11.8 KHz	Hawaii	CW Pulse	10 KW
Omega	13.1 KHz	N. Dakota	CW Pulse	10 KW
Omega	12.3 KHz	La Reunion	CW Pulse	10 KW
Omega	12.9 KHz	Argentina	CW Pulse	10 KW
Omega	12.8 KHz	Japan	CW Pulse	10 KW
Omega	13.0 KHz	Australia	CW Pulse	10 KW
GBR	16.0 KHz	Rugby, England	CW	600 KW
FUB	16.8 KHz	Paris	CW	Not Known
JG2AS	*40.0 KHz	Japan	CW	--
MSF	60.0 KHz	England	CW	--
WWVB	60.0 KHz	Fort Collins, CO	CW	500 KW
DCF-77	*77.5 KHz	Germany	CW	Not Known
NDT	17.4 KHz	Japan	100 Baud MSK	50 KW
NSS	21.4 KHz	Annapolis, MD	200 Baud MSK	400-1000 KW
NWC	22.3 KHz	Australia	200 Baud MSK	1000 KW
NPM	23.3 KHz	Hawaii	200 Baud MSK	60 KW
NLK	24.8 KHz	Jim Creek, WA	200 Baud MSK	234 KW
NAA	24.0 KHz	Cutler, ME	200 Baud MSK	1000 KW

Omega unique frequencies are highly recommended as being most reliable and a station near to most any location in the world. Signals from these stations are 5 each 1 second pulse and then followed by 5 seconds of no signal.

* Note 40 KHz and 77.5 KHz reception require factory installed option.

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MODEL 900A VLF/LF RECEIVER

ADVANTAGES

- Accuracy of parts in 10^{11} over 24-hour period
- Allows traceability to national standards
- Plots minute-to-minute phase record
- Provides all that is necessary for frequency comparison to NBS
- Lowest-cost, most versatile receiver available
- Can be used worldwide

APPLICATIONS

- Monitoring of atomic standards against national standards
- Simple and effective means of checking counter time-base accuracy
- Determining the offset and drift of crystal oscillators.

DESCRIPTION

The Model 900A VLF/LF Receiver compares the phase of a local frequency standard with the received carrier of a frequency stabilized transmitter. Most of the U.S. Navy VLF transmitters, as well as the NBS LF transmitter WWVB, derive their carriers from atomic frequency standards. A local standard can, therefore, be checked with an accuracy approximating one part in 10^{11} using the Model 900A Receiver.

By means of front panel switches, a wide variety of transmissions can be selected in the VLF band from 10 to 25 kHz, or in the LF band from 60 kHz to 75 kHz. *Reception is, therefore, not limited to one or two transmissions as has previously been the case with "economy" model VLF or LF receivers.* Some of the transmissions which can be received strongly in the United States are:

NAA	17.8 kHz	Eastern Maine
NLK	18.6 kHz	Jim Creek, Washington
NSS	21.4 kHz	Annapolis, Maryland
NWC	22.3 kHz	Australia
NBA	24.0 kHz	Canal Zone

(These transmissions can be received even when MSK keying is used.)

An increasing number of Omega transmissions in the 11.0 to 12.0 kHz band

WWVB	60.0 kHz	Fort Collins, Colorado

Other stations which may be received elsewhere in the world are:

MSF	60.0 kHz	Rugby, England
GBR	16.0 kHz	Rugby, England
	40.0 kHz	Japan
	77.5 kHz	Mainflingen, Germany
FUB	16.8 kHz	Paris

The Model 900A Receiver is supplied complete with roof-mounting whip antenna unit, 100 ft. antenna cable, and front panel chart recorder. The Model 900A may be ordered without recorder and a local unit can be used if desired.

SPECIFICATIONS

FREQUENCY COVERAGE:	100 Hz steps from 9.9 kHz to 25.6 kHz 100 Hz steps from 59.9 kHz to 75.6 kHz

SECTION I

INTRODUCTION

The Model 900 VLF/LF Receiver is used to keep track of the offset of a precision local frequency standard with respect to the accurately stabilized carrier frequency of one of the VLF or LF transmitters operated by NBS or by the United States Navy. VLF carriers are typically synthesized from Cesium Beam Frequency Standards located at the transmitters; a long-term frequency accuracy at least as good as one part in $(10)^{11}$ will normally be exhibited by the VLF carrier.

SECTION II

UNPACKING AND INSPECTION

Carefully unpack the receiver and inspect it for possible damage during shipment. Special attention should be given to any areas where the outside shipping package was damaged. If the frequency standard is damaged in any way, immediately notify the carrier. Also notify TREMETRICS Inc., 6500 Tracor Lane, Austin, Texas 78725-2100, 512/929-2051 Attention: Product Service.

SECTION III

INSTALLATION AND OPERATION

Installation and Operation

Use of the receiver is quite simple. Mount the antenna in a clear outdoor area, such as a rooftop. Other conducting objects should be kept at least four feet away from the antenna, and there should be no conductors (such as power lines) at a high elevation angle as viewed from the antenna position.

Connect the antenna coupler to the receiver ANTENNA connector using the coaxial cable provided. Connect 1 MHz (100 kHz optional) from the frequency standard being monitored to the 1 MHz connector of the receiver.

Plug the power cord into a receptacle providing 105-125 volts, 60 Hz. (Operation at 220 V and/or 50 Hz available on special order.)

Initially select a strong nearby transmitter, even if it is desired later to use a different transmitter. Place the VLF/LF switch in VLF position, and set the FREQUENCY switches as shown in Table 1 for the selected transmitter. Within the United States NAA, NLK, or NSS will provide strong signals. Other transmitters not shown in the table may be on at a later date, and in particular there will be a wide selection of transmissions from the various OMEGA transmitters. For a general method of tuning transmitters not shown in the table see page 17.

Turn the front panel GAIN control fully counter-clockwise. The indicator lamp should be extinguished. Turn the GAIN control

TABLE 1

SWITCH SETTINGS FOR VARIOUS TRANSMITTERS

Transmitter	Location	XMTR Freq.	SYNTH Freq.	VLF/LF Switch	Frequency Switches
OMEGA	Trinidad				
GBR	England	16.0	15.9	VLF	U D D U U U U U
NAA	Maine	17.8	17.7	VLF	U D U U D D D U
NLK	Wash State	18.6	18.5	VLF	U D U U U D D U
NSS	Maryland	21.4	21.3	VLF	U U D U D U D U
NWC	Australia	22.3	22.2	VLF	U U D U U U U D
NBA	Canal Zone	24.0	23.9	VLF	U U U D U U U U
WWVB	Colorada	60.0	9.9	LF	D U U D D D U U
MSF	England	60.0	9.9	LF	D U U D D D U U
HBF	Switzerland	75.0	24.9	LF	U U U U U D D U

slowly clockwise. At some point the indicator lamp should come on or begin to blink on and off. When this point is reached, turn the control an additional 1/10 turn clockwise. This provides the optimum gain for the selected transmitter and insures proper reception even though the received signal level should change over a 20 dB range.

Any given transmitter may occasionally be shut down temporarily for maintenance. In the absence of reception from the originally selected transmitter, try a second transmitter.

When a transmitter is first received, the chart recorder needle should move steadily over a period of some 10 seconds to one minute and reach a position where it remains fairly stationary.

For a strong signal the indicator light should come on well below the maximum GAIN position. At maximum gain the lamp may flicker as a result of atmospheric noise reception. When reception is normal, and the GAIN setting proper, switching the <u>third FREQUENCY switch from the right</u> away from the correct position should usually cause the indicator lamp to go out. Keep a record of gain setting for each transmitter normally used. This will be a useful guide in recognizing later transmitter shutdowns.

Various chart indications of proper tracking will become familiar after a few days of operation. The diurnal shift pattern is one such indicator. The CEC reading should <u>increase gradually</u> as the sunset line moves westward along the path between transmitter and receiver. The CEC decreases at sunrise may not be smooth and gradual.

<u>Chart Recorder Adjustments</u>

The chart recorder should be checked occasionally for correct zero and full-scale indications. Depress the RCDR ZERO toggle on the front panel. The recorder should now give a reading of zero. If not, adjust the recorder mechanical zero.

Next depress the FULL SCALE toggle. The recorder should now read 100 CEC. If not, adjust the RCDR FS ADJ available through the front panel access hole.

<u>Choice Of A Transmitter</u>

Normally the transmitter providing the strongest signal will be selected for continuous frequency monitoring. In some

cases a transmitter at a particular short range may give erratic results at sunrise. Try each of several strong transmitters for a period of several days and select one with a stable diurnal shift pattern.

Interpretation of Chart Records

Frequency offset of the local frequency standard with respect to the VLF carrier is determined from the chart record produced by the receiver. In general the offset is determined as follows:

Let Δt be the phase change noted on the chart expressed in microseconds.

Let ΔT be the elapsed time interval over which the change occurs, expressed in seconds. The fractional frequency offset is then

$$\frac{\Delta t}{\Delta T} \times (10)^{-6}$$

In other words, a phase rate of one microsecond per second corresponds to a fractional frequency deviation of 1 part in $(10)^6$.

Δt is determined from the chart record. Full scale deflection corresponds to 1 cycle of phase at the VLF carrier. It will prove most convenient to read phase change in hundredths of a cycle, or centicycles, and then convert to microseconds. At 17.8 kHz, for example, the frequency transmitted from Cutler, Maine, full scale is 56.2 microseconds. To convert from CEC to µs multiply by 0.562. Suppose, for example, that over a 24-hour

period from noon to noon, the phase reading increases by 7 CEC. This corresponds to 7 x 0.562 = 3.9 μs. Twenty-four hours is 86,400 seconds. So the fractional frequency offset is

$$\frac{3.9}{8.64(10)^4} (10)^{-6} = 4.5 \times 10^{-11}$$

An increasing phase reading indicates that the local frequency is high. A decreasing phase reading indicates that the local frequency standard is low in frequency.

C_A_U_T_I_O_N

THE FOREGOING DETERMINATION OF WHETHER THE LOCAL STANDARD IS HIGH OR LOW IN FREQUENCY ASSUMES THAT THE SYNTHESIZED LOCAL OSCILLATOR SIGNAL IS 100 HZ BELOW THE CARRIER AS RECOMMENDED IN THE OPERATING INSTRUCTIONS AND SET-UP TABLES IN THIS MANUAL. IF RECEPTION IS EFFECTED BY PLACING THE LOCAL OSCILLATOR 100 HZ ABOVE THE CARRIER, THE SENSE OF THE READOUT WILL BE REVERSED.

Figure 1 gives in graphic form the conversion from centicycles to microseconds, while figure 2 permits graphic determination of fractional frequency offset.

Several facts must be understood in order to interpret properly the receiver records. First of all, propagation time from the transmitter to the receiver is not precisely constant. In particular, there is a marked difference between daytime and nighttime delay. This change is known as the "diurnal shift" and results from the change in the height of the ionosphere. Nighttime propagation is slower than daytime propagation by some tens of microseconds. The delay is most stable when the entire path is in daylight. Repeatability from day to day is usually accurate to approximately one microsecond. At night

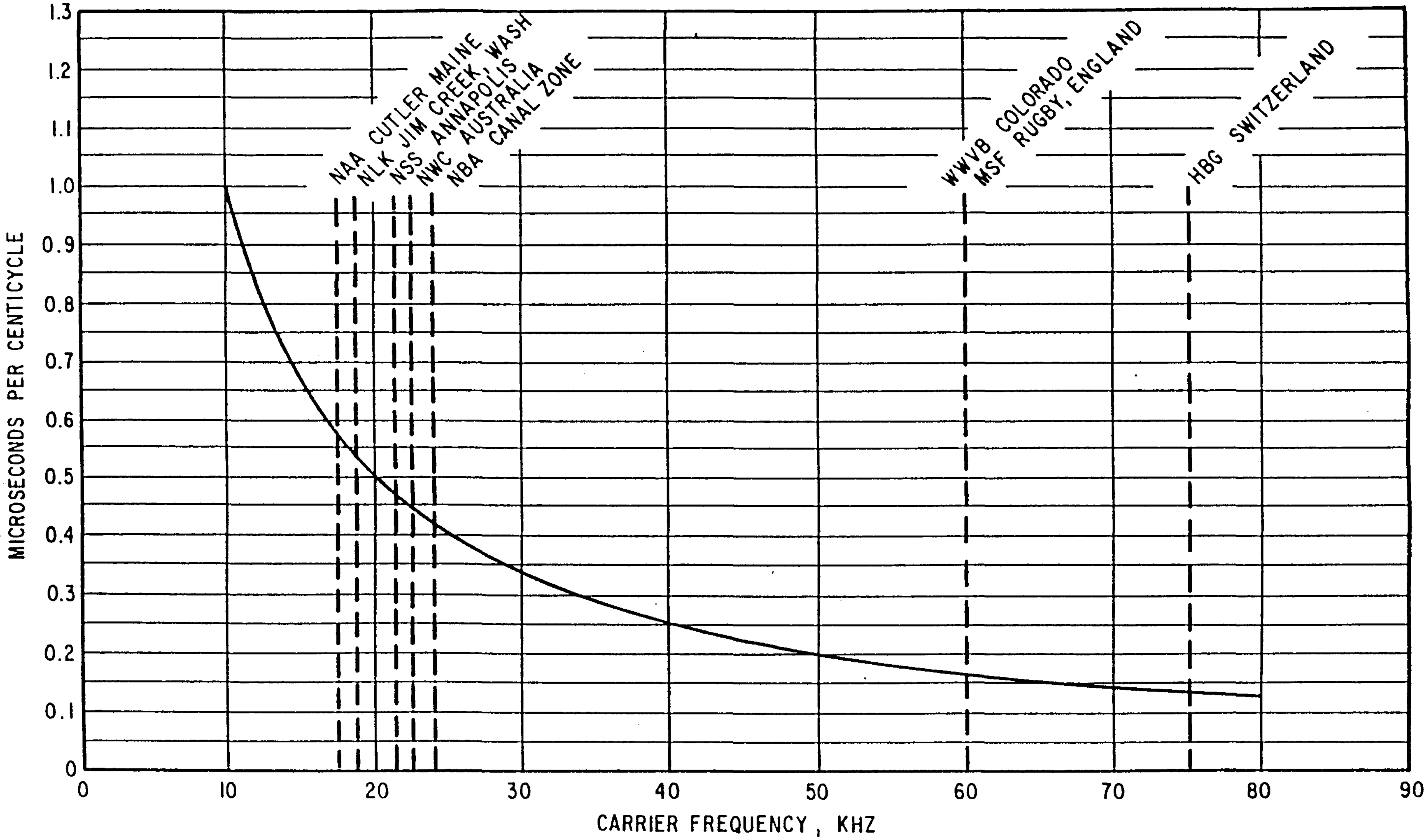

FIGURE I CONVERSION FROM CENTICYCLES TO MICROSECONDS

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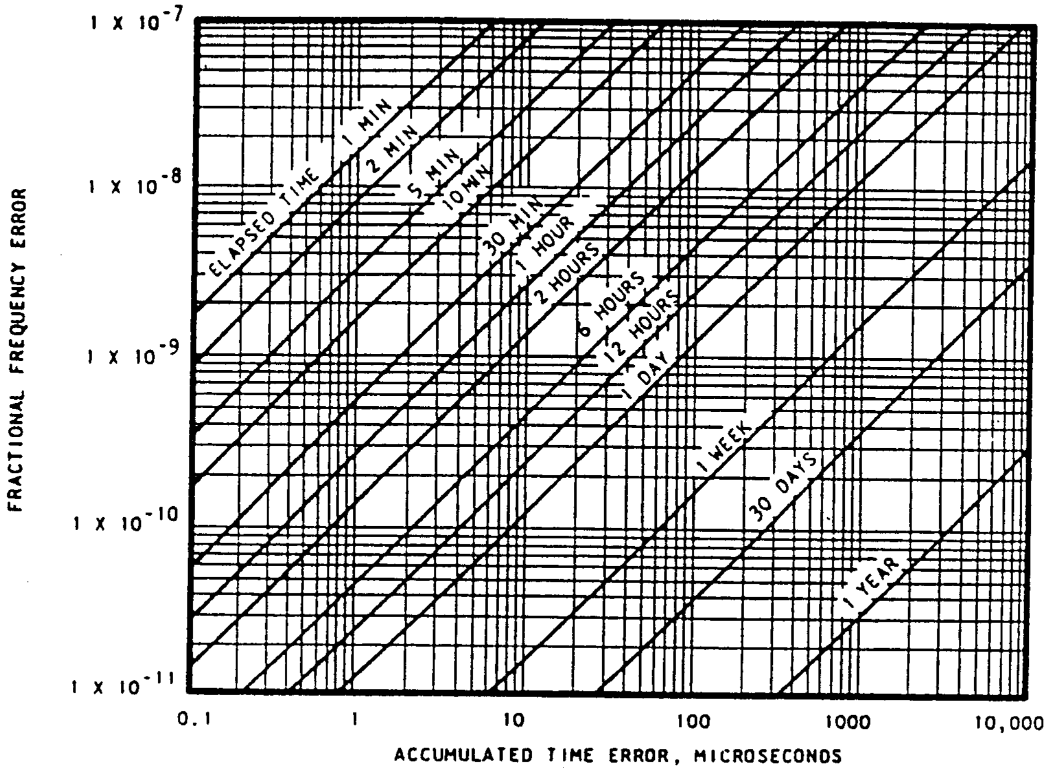

Figure 2 Fractional Frequency Error Chart

random fluctuation of five to ten microseconds or more often occur. Thus the best results are obtained by taking readings at the same time each day; the time selected should be one during which the transmission path is entirely in daylight. The entire chart should be examined in the neighborhood of the selected time to insure that the appearance is normal. This is desirable because occasionally a solar flare can affect propagation delay for an hour or two, and a reading taken during such a time interval would lead to inferior results. With care, an accuracy approaching one microsecond can be achieved over a period of one day. This results in a frequency measurement accuracy approaching 1 part in $(10)^{11}$.

Fortunately frequency standards which are sufficiently stable to make readings to a part in $(10)^{11}$ meaningful are also stable enough so that a day's elapsed time does not result in a change in frequency which is much greater than a few parts in $(10)^{11}$. Or, to put it another way, if a standard shifts so rapidly that a measurement must be made in a period much shorter than one day, then an accuracy of parts in $(10)^{11}$ is seldom required. Utilizing a period of all-daylight reception, a frequency determination at least as gcod as one part in $(10)^9$ can usually be achieved in an hour or two.

Figure 3, 4, and 5 are three representative chart recordings from the Model 900 Receiver.

Figure 3 shows reception of WWVB, 60 kHz. Note the gradual increase of phase after 4 PM at the right hand edge of the upper strip chart record and the left hand edge of the center record. This is the evening diurnal shift.

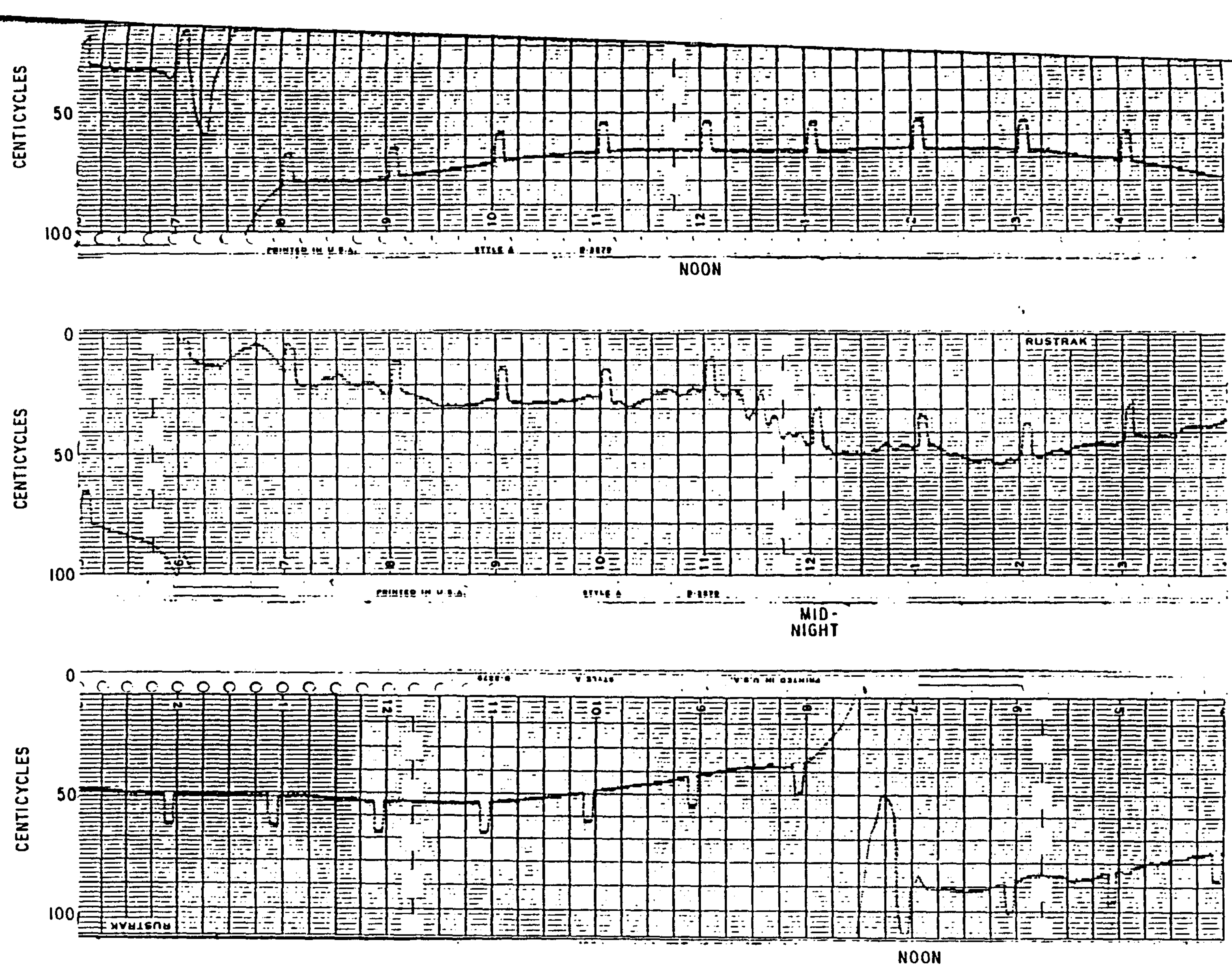

FIGURE 3 WWVB (60KHZ) AS RECEIVED AT AUSTIN, TEXAS
OSCILLATOR OFFSET APPROXIMATELY -2.3×10^{-11}

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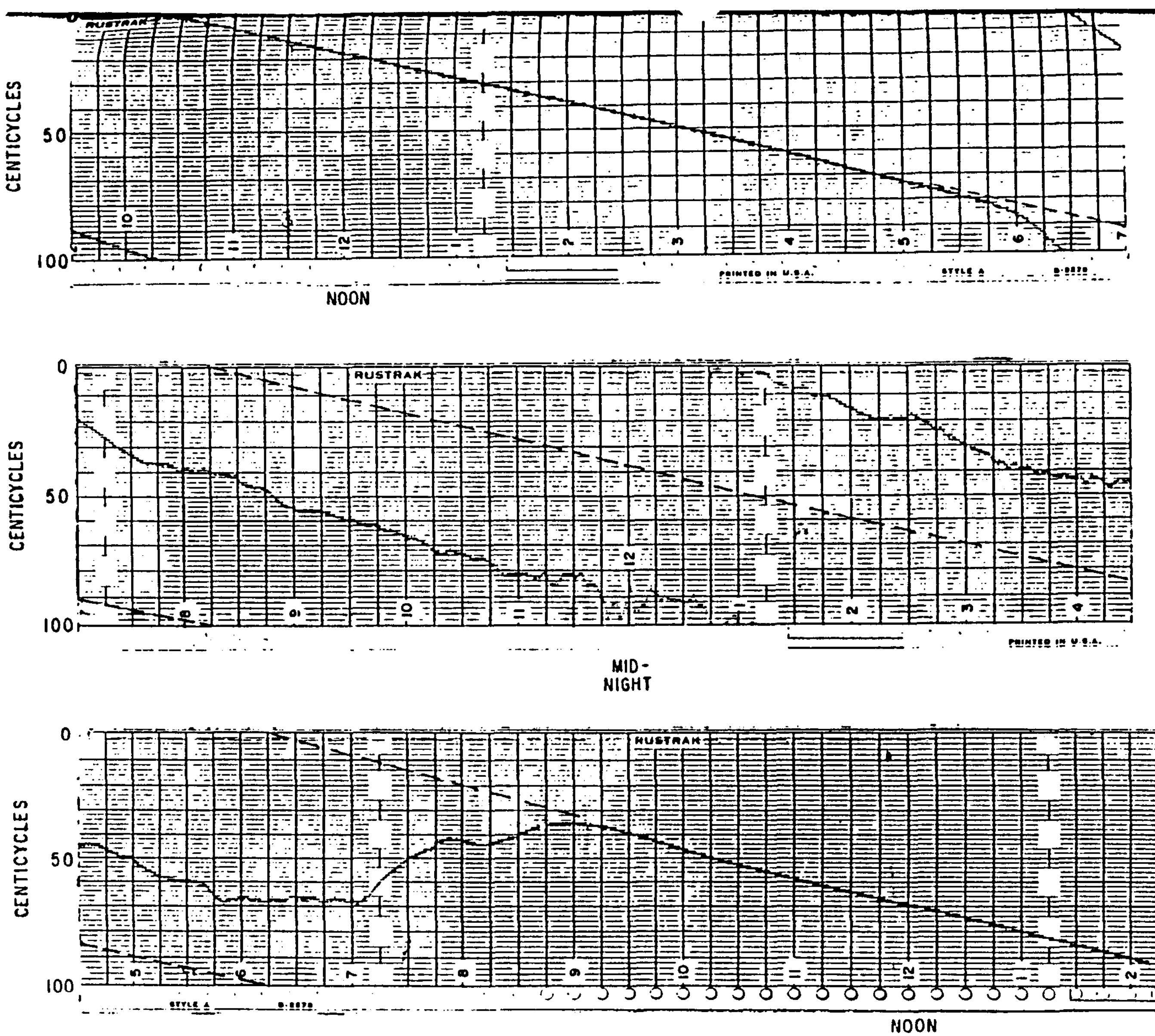


FIGURE 4 NLK (18.6 KHZ) AS RECEIVED AT AUSTIN, TEXAS
OSCILLATOR OFFSET APPROXIMATELY + 1.6 x 10^{-9}

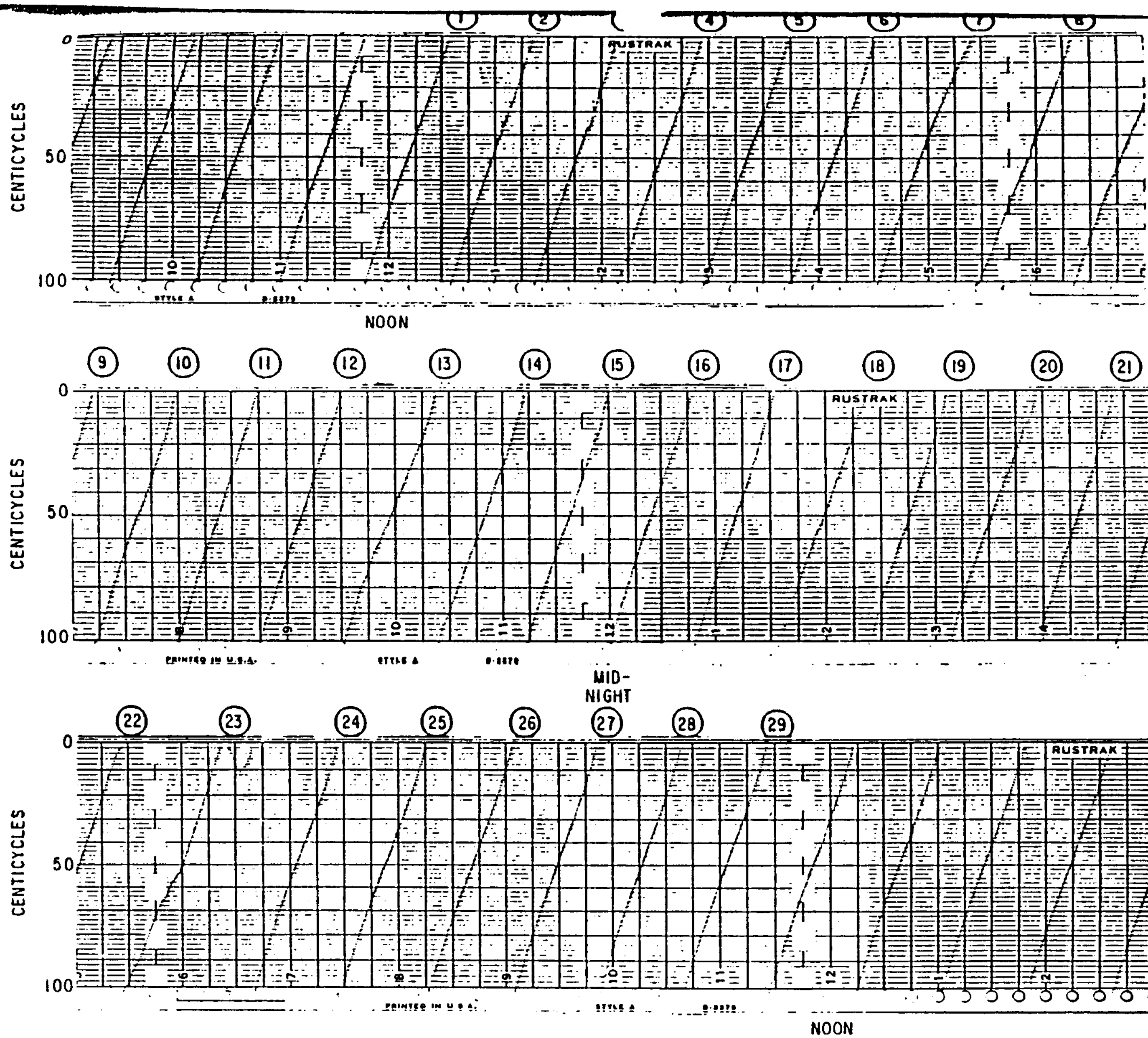


FIGURE 5 NAA (17.8KHZ) AS RECEIVED AT AUSTIN, TEXAS
OSCILLATOR OFFSET APPROXIMATELY -1.9×10^{-8}

Note also the apparent sudden jump from 100 CEC to 0 CEC at 6 PM near the left of the center strip. The total range of the phase detector is 100 CEC, or one full cycle of phase, When one extreme is reached the record reverts to the other extreme. If the phase just before 6 PM is 99 CEC, the phase just after 6 PM is obviously not 1 CEC, but 101 centicycles. It is necessary to count cycle accumulation in this fashion when reading a chart record. This will become clearer in the two later examples.

The sunrise effect between 7 and 8 AM on the lower strip is not so smooth and gradual as the evening shift. Looking at this area alone, it might not be easy to determine whether a cycle could perhaps have been gained or lost. Looking at the daytime record, however, it is clear that there is approximately zero average slope so that the record returns to the same cycle the second day as the first.

Note also that the daylight record is rather smooth, while the nighttime record "wanders" back and forth a number of centicycles in the course of an hour or two.

Note also the phase shift lasting approximately five minutes of each hour. This shift is introduced at the WWVB transmitter. Its presence in the recording is a definite indication of proper phase tracking.

At noon the first day the reading is 67 CEC. At noon the second day the reading is 56 CEC. The 24 hour change is then 56 - 67 = -11 CEC.

Referring to figure 1, at 60 kHz the number of microseconds per centicycle is 0.167. The change expressed in microseconds then is

$$0.167\ (-11) = -1.837\ \mu s.$$

Referring to figure 2, 1.837 μs in 24 hours is an offset of 2.3 parts in $(10)^{11}$. Since the change is negative the local frequency standard was low by 2.3 parts in $(10)^{11}$.

Figure 2 shows reception of NLK, Jim Creek, Washington, at 18.6 kHz. Here there is an obvious gradual phase increase with time. The evening shift beginning about 6 PM is easily recognized. The smooth daytime and more variable nighttime characteristics are obvious. The sunrise shift in this case is fairly smooth.

Clearly there is a cycle change near 6:30 PM the first day, and near 1 AM. The reading at noon the first day is 17 CEC. Clearly by noon the second day two additional cycles have been accumulated and the reading is taken not simply as 69, but as 269. A dashed line has been added showing a continuation of the steady daytime slope. This verifies that exactly two cycle changeovers have occurred.

The change is 269 - 17 = 252 CEC. From figure 1, at 18.6 kHz one CEC is 0.54 μs, so the 24 hour change is

$$(253)(0.54) = +137\ \mu s$$

From figure 2 this represents a frequency offset of 1.6×10^{-9}. Since the change is positive the oscillator frequency is high.

An approximation could have been obtained over a shorter period of time. At 2 PM the first day the reading is 38 CEC. The change since noon is then

$$38 - 17 = 21 \text{ CEC, or}$$
$$(21)(0.54) = 11.3\ \mu s$$

By calculation 11.3 μs in 2 hours is

$$\frac{11.3}{(2)(3600)} \times 10^{-6} = 1.7 \times 10^{-9}$$

This last result could, of course, be obtained from Figure 2 instead of making the calculation.

Figure 5 illustrates a more radical oscillator offset. From noon the first day to noon the second there are 29 cycle crossovers. These have been numbered on the chart reproduction. Since the reading is decreasing it is easiest to take the final reading as 30 CEC. The initial reading is then 2973, and the change is -2943.

From Figure 1, at 17.7 kHz, 1 CEC is 0.56 μs. The change is (-2943)(0.56) = - 1655 μs. This corresponds to a frequency offset of 1.9×10^{-8}.

With so great an offset, there is normally little to be gained by seeking the accuracy inherent in a 24 hour reading. For example, there is a complete cycle between 11 on the first day and about 11:47. 100 CEC is 56 μs. 56 μs in 47 minutes is, from figure 1, about 1.8×10^{-8}.

Calculation of Frequency Switch Settings

The most frequently used frequency settings have been given in Table 1. It is relatively easy to calculate any desired setting. The switches select the frequency in binary form as follows:

	Switch	Binary Value (multiple of 100 Hz)
(LEFT)	S208	128
	S207	64
	S206	32
	S205	16
	S204	8
	S203	4
	S202	2
(RIGHT)	S201	1

When the switch is UP, the corresponding number is added in. With the switch DOWN, the number is omitted.

Suppose, for example, that it is desired to select 18.5 kHz in order tc receive the VLF carrier at 18.6 kHz. The desired multiple of 100 Hz is 185. S208 is placed up contributing 128 toward the required 185. The difference 185 - 128 = 57 must be supplied by the remaining switches. Clearly 64 would be too much, so S207 is placed down, omitting 64. S206 is placed up, providing 32 of the required 57. The remaining switches must supply 57 - 32 = 25. S205 is placed up, providing 16, and leaving a requirement for 9. S204 is placed up supplying 8 of the 9. S203 and S202 are then placed down, while S201 is placed up, providing the last 1. To summarize in tabular form:

S208	128	X1 (UP)	=	128
S207	64	X0 (DOWN)	=	0
S206	32	X1 (UP)	=	32
S205	16	X1 (UP)	=	16
S204	8	X1 (UP)	=	8
S203	4	X0 (DOWN)	=	0
S202	2	X0 (DOWN)	=	0
S201	1	X1 (UP)	=	1
		TOTAL		185

SECTION IV

THEORY OF OPERATION

A block diagram of the Model 900 LF/VLF Receiver is given in figure 6.

The signal is received by a vertical whip antenna mounted on the antenna coupler unit. A pre-amplifier in the coupler provides approximately unity voltage gain while converting the impedance to a level which can drive the 50-ohm cable feeding the main receiver unit.

With the LF/VLF switch in VLF position the signal goes directly to the R-F amplifier. (For LF reception the signal is converted down by mixing with a 50 kHz local oscillator signal.) Another local oscillator signal is synthesized at a frequency 100 Hz below the desired VLF signal frequency. Mixer action converts the r-f signal to 100 Hz for amplification by an I-F amplifier tuned to 100 Hz.

The 1 MHz signal from the frequency standard being tested is used to produce signals at various frequencies including the local oscillator signals at 50 kHz and at f_0 - 100 Hz. Two signals are produced at 100 Hz, one by simple division, the other by a divider circuit which includes provision for adding inhibiting pulses, thus advancing or retarding the phase of the resulting 100 Hz. The shifted 100 Hz signal is used as a reference signal in a synchronous detector. If the phase difference between the 100 Hz reference and the 100 Hz I-F signal is exactly 90°, no error signal is produced and the phase of the

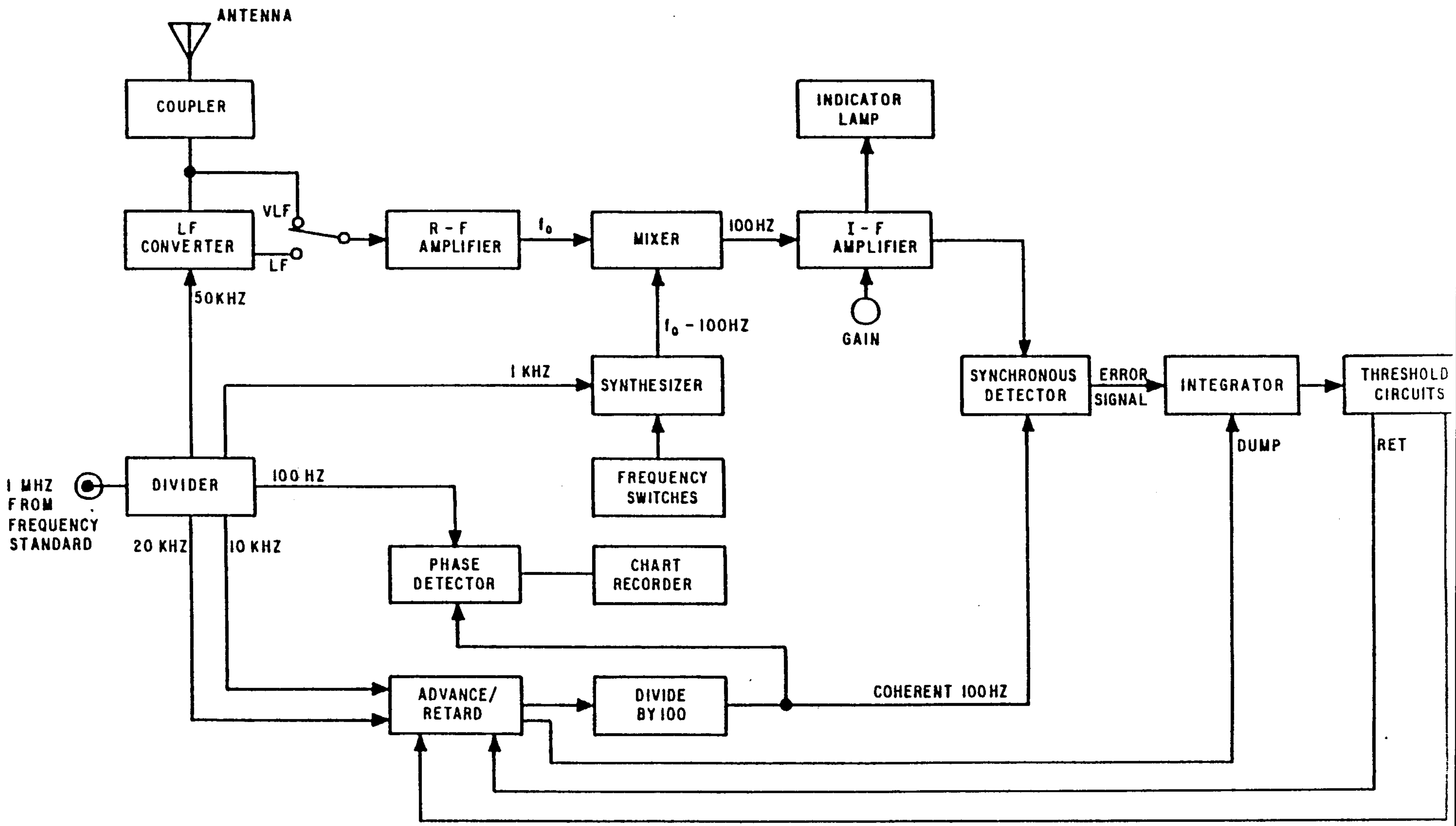


Figure 6. Block Diagram, VLF Receiver Model 900

reference signal is maintained constant. If the phase difference is temporarily less than 90°, retard pulses are repeatedly generated until the phase difference is 90°. If the phase difference is temporarily greater than 90°, repeated advance pulses are generated. Thus closed loop action phase locks the coherent 100 Hz signal 90° away from the I-F signal phase.

Any phase change in the received signal thus results in a corresponding phase change in the coherent 100 Hz signal. Phase comparison of the coherent 100 Hz with respect to the fixed-phase 100 Hz signal produced by direct division provides a chart recorded signal representation of the phase of the incoming VLF carrier (with reference to the local frequency standard). The change in phase measured over a period of one day then serves to indicate the amount of frequency offset existing in the local standard with respect to the atomic frequency standard being used to stabilize the VLF transmission.

Detailed Circuit Theory

Antenna Coupler

Figure is a schematic of the antenna coupler. FET Q1 is a high-input impedance low-noise amplifier as required by the high-impedance whip antenna. A surge voltage limiter and two back-to-back zener diodes are included in the input circuitry to protect the other circuit elements from high voltage surges caused by nearby lightning strikes. RC filtering attenuates signals above 100 kHz.

Amplifiers Q2 and Q3 provide additional gain, while emitter follower Q4 provides a low output impedance to drive the

cable feeding the main receiver. DC voltage is supplied via the center conductor of the coxial cable.

Figure is a schematic diagram of the receiver proper. For convenience the circuits are subdivided into sections as follows:

Section Title	Typical Reference Designator
Divider	R101
Synthesizer	R201
Synchronous Detector	R301
R-F/I-F	R401
Power Supply	R501
LF-to-VLF Converter	R601

Each circuit group occupies a separate section of the printed circuit card.

R-F/I-F Circuits

The signal from the antenna coupler enters at TP405. Power for the coupler is supplied through R446. L401 and C420 provide additional rejection of signals above 100 kHz.

With S501 in VLF position the incoming signal goes directly to amplifier U401, pin 3. Two amplifier sections with a total voltage gain of approximately 200 precede the mixer Q404. The synthesizer signal at the gate of Q404 is chosen 100 Hz below the VLF carrier producing an output to U402, pin 11 at a frequency of 100 Hz. After amplification by three sections of U402 the signal reaches an active bandpass filter (U403D, C410, C411, R424, etc.). This stage is tuned to 100 Hz with a Q of approximately 10.

The next section of U403(C) feeds a limiter (CR1, CR2, etc.) which insures constant level I-F signal at the synchronous detector. The limited signal is amplified in the final section of U403(B) and applied to the synchronous detector section via emitter follower Q403.

Q401 acts as a detector and amplifier for the signal. Amplifier Q402 drives indicator lamp DS1. In the absence of I-F signal DS1 is dark. With adequate I-F signal present DS1 is lit. DS1 thus serves as a guide in setting gain control R416 to provide adequate but not excessive I-F signal level.

For LF reception the signal is amplified by Q601 and Q602. High pass filter L602, 609, etc. rejects possible very strong VLF signals which might pass directly through and interfere with the desired LF signal reception. The LF signal is mixed with 50 kHz at mixer Q603. An LF signal at 60 kHz, for example, would then produce an output at 10 kHz at the junction of R614 and C615. The filter consisting of C615, R617, etc. notches out the 50 kHz local oscillator signal. The filter output goes to U401, via S501 in the LF position.

Divider Circuit Group

The 1 MHz signal from the frequency standard enters at E101, and is buffered and shaped by Q101 and U105A. The shaped 1 MHz serves as a clock signal for a divider chain consisting of decade dividers U101, 102, 103, and 104 which produce 100 kHz, 10 kHz, 1 kHz and 100 Hz respectively.

The 100 kHz signal from U101 is frequency divided by 2 to 50 kHz by J-K flip flop U107B. The 50 kHz output is used as the local oscillator signal for mixing LF signals (such as 60 kHz) down to the VLF band.

U102 receives 100 kHz at pin 1 and frequency divides by 5, producing 20 kHz at pin 11. This 20 kHz signal is fed back into the divide by 2 section at pin 14, producing 10 kHz at pin 12.

The 20 kHz signal at U102, pin 11 and the 10 kHz signal at U102, pin 12 are utilized in the ADVANCE/RETARD circuit. The two signals are fed together to NAND gate U105B. The output of U105B is ground only when <u>both</u> the 20 kHz signal and the 10 kHz signal are positive. The result is a negative pulse of 25 μs duration occurring each 100 μs at U105, pin 6.

Similarly the 20 kHz signal is combined with an inverted version of the 10 kHz signal at U105D to produce a second 25 μs pulse displaced 25 μs in time from the first, at U105, pin 11.

As will be shown presently, the "retard gate" line at U106, pin 2 is normally negative. Thus the output at U106, pin 1 goes positive for 25 μs of each 100 μs. The "advance gate" line at U106, pin 5 is normally positive, holding U106, pin 4 continuously at ground. Under these conditions the signal at U106, pin 13 is positive for 75 μs of each 100 and negative for 25 μs of each 100. the repetition period is, of course, 10 kHz. The 10 kHz signal is frequency divided to 100 Hz by U108 and U109.

Each output from U109 triggers one-shot U111. The period of the one-shot is just over 100 μs, or one cycle at 10 kHz. A

positive pulse is produced at pin 6 which feeds U113B. A negative pulse at pin 1 feeds U112A. If a positive signal exists on the advance enable input at U113, the occurrence of the positive pulse at pin 5 results in a negative pulse at U113, pin 6. This is applied as the advance gate at U106, pin 5. This permits the negative pulse at U106, pin 6 to create a positive pulse at U106, pin 4 and a negative pulse at U106, pin 13. The pulse at U106, pin 13 is in addition to the train of pulses normally passing at a 10 kHz rate through U106A and U106D. Thus an extra clock pulse is applied to U108, and the 100 Hz output signal at U109, pin 12 is advanced by 1/100 of a cycle, or one centicycle, of phase.

If a negative retard enable signal exists at U112, pin 3, the negative pulse from the one-shot at U112, pin 2 produces a positive pulse at U112, pin 1. This is fed as the retard gate to U106, pin 2. This positive signal inhibits passage of one pulse of the 10 kHz pulse train normally transmitted via U106A. This results in one lost clock pulse at U108, pin 1, and a phase retardation of 1 centicycle in the 100 Hz output from U109.

When either the positive or the negative one-shot pulse is enabled, a negative pulse results at U112, pin 13. This triggers one-shot U114 which produces a "dump pulse". Use of this dump pulse and the generation of the retard enable and advance enable signals will become clear in the later discussion of the synchronous detector circuits group.

U107A serves as a linear phase detector. The 100 Hz output of U109 which is phase locked to the received signals is phase compared with the 100 Hz output of U104 derived by direct division from the frequency standard. The output of U109 clocks the flip flop U107A to the $\overline{Q}$ zero state; a short one-shot pulse derived

from the 100 Hz output of U104 clears the flip flop to the $\overline{Q}$ positive state. If the clear pulse follows very quickly after the clock pulse $\overline{Q}$ is zero only a small fraction of one cycle at 100 Hz, and is positive the rest of the time. If there is a delay of nearly a full cycle between clock and clear, $\overline{Q}$ is zero nearly all the time. The DC level at $\overline{Q}$ is thus a linear measure of the relative phase between the 100 Hz signals from U109 and from U104.

This signal is applied via R103 and R104 to the chart recorder. S101 is a hold-to-open spring loaded toggle. When the toggle is actuated U107A is clocked to $\overline{Q}$ zero and is not again cleared to a $\overline{Q}$ positive as long as S101 is operated. S101 thus serves to ZERO the chart record. When spring loaded toggle S102 is held open U107A is cleared to $\overline{Q}$ positive and is not again clocked to $\overline{Q}$ zero. S102 thus serves as a FULL SCALE actuator for the recorder. While S102 is held open, the recorder deflection is adjusted for 100 CEC using variable resistor R104.

Power for the integrated circuits is obtained from 6-volt regulator U115 which in turn is powered via R107 and R108 from the 12 volt regulator in the main power supply circuit section.

Synthesizer Circuit Group

The synthesizer circuit which produces a signal 100 Hz below the received carrier consists basically of voltage controlled oscillator U202, phase comparator U201, and preset dividers U205 and U206. The dividers are set to divide the oscillator frequency by a number N. The oscillator frequency is controlled by the phase detector output so that the divider output f_{osc}/N is phase locked to the 1 kHz input. Then

$$f_{osc}/N = 1 \text{ kHz}$$

$$\text{or,} \quad f_{osc} = N \times 1 \text{ kHz}$$

The oscillator signal is frequency divided by 10 in decade divider U204. The output frequency $f_{osc}/10$ is thus

$$f_{osc}/10 = N \times 100 \text{ Hz.}$$

Clearly then the synthesizer will produce any integral multiple N x 100 Hz which can be selected in U205 and U206. The maximum N is one less than 16 x 16, or 255, permitting direct reception of signals up to 25.6 kHz.

The dividers are loaded under control of the front panel FREQUENCY toggles. The dividers count down to zero and are then reloaded to the preselected number N by the output pulse at U205 pin 13 fed back to <u>load</u> <u>inputs</u> pin 11 of each counter.

The switches select the number N in binary form. Thus N = 128 corresponding to a synthesized frequency of 12.8 kHz would result from a switch setting of

S208	UP (1)
S207	DOWN (0)
S206	DOWN (0)
S205	DOWN (0)
S204	DOWN (0)
S203	DOWN (0)
S202	DOWN (0)
S201	DOWN (0)

This would be the desired setting for reception of a carrier at 12.9 kHz. See page 4 for a more detailed description of switch settings.

Synchronous Detector Circuit Group

The synchronous detector circuit group receives the I-F signal from the receiver circuit group and the shifted 100 Hz signal from the divider section. The I-F signal is shorted out via Q302 during one half-cycle of the 100 Hz reference. During the other half cycle the I-F signal is passed through to integrator circuit U302. If the reference signal is 90° out of phase with the I-F, equal positive and negative portions of the I-F signal are passed through, so net DC input to the integrator is zero (with respect to the 5-volt reference level).

If the reference signal at R304 is in phase with the I-F signal at C304, the I-F signal is shorted out during its negative half-cycle and passed during its positive half cycle. Thus a net positive DC (with respect to the 5-volt reference level) is supplied to the integrator. Similarly, if the reference is 180° out of phase with the I-F, a net negative signal reaches the integrator input.

If a positive input reaches the integrator, the integrator output runs gradually in a negative direction from the 5-volt reference level. When a voltage of approximately 3 volts is reached, voltage comparator U303A goes suddenly positive at output pin 4. This turns on Q306 producing a ground level retard enable signal in the divider section. As previously shown this causes the reference phase to be retarded by 1 CEC, and produces a negative "dump pulse". This dump pulse turns off Q304, which turns on FET Q303. This gives a direct low impedance feedback path across integrator capacitor C306, and quickly returns the output of U302, pin 6 to the 5-volt reference level.

If the 1 CEC phase shift is inadequate to bring the reference signal to quadrature with the I-F so that a positive polarity exists as before at the integrator input, the entire cycle just described is repeated. When successive phase retardations finally bring the reference to the other side of quadrature, a negative input to the integrator results, and the integrator output goes gradually positive. At about 7 volts it causes voltage comparator U303B output to go negative, cutting off Q305, and producing a positive advance enable signal. This results in a 1 CEC advance of the reference phase and a "dump pulse" to restore the integrator to 5 volts. In the steady state the reference signal goes from side to side of the quadrature position by a fraction of a centicycle, producing alternate advance and retard pulses.

Regulator U301 produces the 5-volt reference level used in the phase detector circuit section and also in the receiver section.

The power supply circuit which produces the regulated 12-volt supply for the various circuits is extremely simple. (See figure .) AC power is applied to T501. The secondary voltage goes to a bridge rectifier consisting of CR501 through CR504. The ripple is smoothed by C503, producing a DC input to R501 of approximately 32 volts (depending upon the exact line voltage). The current drain of the entire receiver is some ½ ampere. There is therefore a drop of some 15 volts across 30 ohms consisting of resistors R501, R502 and R503 in series permitting some 17 volts at the input of U501.

The LM309 holds the voltage between pins 2 and 3 at 5 volts. This results in 12 volts to ground at output pin 2.

SECTION V
REPLACEABLE PARTS

Ordering Information

Address orders or inquiries to either an authorized TREMETRICS Inc., Sales Representative or to:

TREMETRICS Inc.
Industrial Instruments
Customer Service
6500 Tracor Lane
Austin, Texas 78721

For prompt service, orders should include:

a. Name, model, and serial number of the instrument.
b. TREMETRICS stock number
c. Full description of the part.

Part numbers on parts lists may change occasionally as items are reevaluated or as improved components become available. The part shipped will be the part used in production at the time the order is received, and will be equivalent to the part it replaces in both dimensions and performance.

SPL020 MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	TRIMETRICS STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
* * *	* ASSEMBLY NO ..19308-0001	PCB ASSY RECEIVER	* * * *	
1	..19307	PCB,RECEIVER		
28	..79603	DIA SCH 900 J/K MSK		
57	...3878-0051	HEAT SINK		
59	...4239-0020	SCR PAN HD 4-40X5/16		
87	..76329-0001	SOCKET IC 14 PIN		
88	..76329-0002	SOCKET IC 16 PIN		
89	..76329-0003	SOCKET IC 8 PIN		
90	..76336-0001	HEATSINK TO5		
96	..19357	DIA SCH RCVR PCB		
106	..19410	JIG,SOLDERING		
107	610-0093	TERMINAL SOLDER		
109	82	INSULATOR TSTR PAD		
C 1	..24113-9102	CAP FXD CER .1 MFD		
C 2	...3322-9102	CAP FXD CER .1 MFD		
C 3	...3322-9102	CAP FXD CER .1 MFD		
C 4	...3322-9102	CAP FXD CER .1 MFD		
C 5	...3322-9102	CAP FXD CER .1 MFD		
C 6	...3322-9102	CAP FXD CER .1 MFD		
C 7	..76321-0005	CAP FXD MYLAR .1 UF		
C 8	..76321-0005	CAP FXD MYLAR .1 UF		
C 9	..76321-0011	CAP FXD MYLAR .05 UF		
C 10	..76321-0011	CAP FXD MYLAR .05 UF		
C 11	...3322-9102	CAP FXD CER .1 MFD		
C 12	..23195-0007	CAP FXD TA 10 MFD		
C 13	...3322-9102	CAP FXD CER .1 MFD		
C101	...3403-9103	CAP FXD CER .01 UF		
C103	..27513-0102	CAP FXD MICA 1000 PFD		
C104	...3324-9153	CAP FXD MYL .015 MFD		
C105	..21485-9101	CAP FXD TA 1 MFD		
C106	...3954-0042	CAP FXD ELEC 50 MFD		
C107	...3321-9102	CAP FXD CER .1 MFD		
C109	...3954-0016	CAP FXD ELEC 100 MFD		
C111	...3954-0016	CAP FXD ELEC 100 MFD		
C112	...3321-9102	CAP FXD CER .1 MFD		
C113	...3321-9102	CAP FXD CER .1 MFD		
C114	...3321-9102	CAP FXD CER .1 MFD		
C115	...3321-9102	CAP FXD CER .1 MFD		
C201	...3321-9102	CAP FXD CER .1 MFD		
C202	..23195-0043	CAP FXD TA 100 MFD		
C203	...3321-9102	CAP FXD CER .1 MFD		
C204	..23969-0009	CAPACITOR 1 MFD		
C206	..23195-0043	CAP FXD TA 100 MFD		
C207	...3321-9102	CAP FXD CER .1 MFD		
C208	...3321-9102	CAP FXD CER .1 MFD		
C209	..27512-0182	CAP FXD MICA 1800 PFD		
C210	...3321-9102	CAP FXD CER .1 MFD		
C211	..23195-0043	CAP FXD TA 100 MFD		
C212	...3321-9102	CAP FXD CER .1 MFD		
C213	...3321-9102	CAP FXD CER .1 MFD		
C214	...3321-9102	CAP FXD CER .1 MFD		
C215	...3321-9102	CAP FXD CER .1 MFD		
C301	..24113-9102	CAP FXD CER .1 MFD		
C302	...3954-0042	CAP FXD ELEC 50 MFD		
C303	...3321-9102	CAP FXD CER .1 MFD		
C304	...3954-0004	CAP FXD ELEC 10 MFD		
C305	..27512-0151	CAP FXD MICA 150 PFD		
C306	..76321-0006	CAP FXD MYLAR 2.0 UF		
C307	...3321-9102	CAP FXD CER .1 MFD		
C308	...3954-0004	CAP FXD ELEC 10 MFD		
C401	...3322-9102	CAP FXD CER .1 MFD		
C402	..27513-0681	CAP FXD MICA 680 PFD		
C403	..27513-0102	CAP FXD MICA 1000 PFD		
C404	...3321-9102	CAP FXD CER .1 MFD		
C405	...3321-9102	CAP FXD CER .1 MFD		
C406	..27512-0272	CAP FXD MICA 2700 PFD		
C407	...3321-9102	CAP FXD CER .1 MFD		
C408	...3321-9102	CAP FXD CER .1 MFD		
C410	..76321-0005	CAP FXD MYLAR .1 UF		
C411	..76321-0005	CAP FXD MYLAR .1 UF		
C412	...3321-9102	CAP FXD CER .1 MFD		
C413	..27512-0471	CAP FXD MICA 470 PFD		
C414	..23969-0009	CAPACITOR 1 MFD		
C415	...3321-9102	CAP FXD CER .1 MFD		
C416	..21485-9101	CAP FXD TA 1 MFD		
C417	...3321-9102	CAP FXD CER .1 MFD		
C418	..24182-0102	CAP FXD AL 1000MF 25V		
C419	..23195-0027	CAP FXD TA 22 MFD		
C420	...3324-9224	CAP FXD MYL .0022 MFD		
C443	...3321-9102	CAP FXD CER .1 MFD		
C601	...3321-9102	CAP FXD CER .1 MFD		
C602	...3954-0042	CAP FXD ELEC 50 MFD		
C603	...3321-9102	CAP FXD CER .1 MFD		
C604	...3321-9102	CAP FXD CER .1 MFD		

REFERENCE DESIGNATION	T E C H E T R I C S STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
C605	...3324-9224	CAP FXD MYL .0022 MFD		
C606	...3321-9102	CAP FXD CER .1 MFD		
C607	...3321-9102	CAP FXD CER .1 MFD		
C608	...3324-9103	CAP FXD MYL .01 MFD		
C609	...3324-9224	CAP FXD MYL .0022 MFD		
C610	...3324-9224	CAP FXD MYL .0022 MFD		
C611	...3324-9683	CAP FXD MYL .068 MFD		
C612	...3321-9102	CAP FXD CER .1 MFD		
C613	...3321-9102	CAP FXD CER .1 MFD		
C614	..27513-0561	CAP FXD MICA 560 PFD		
C615	..27512-0271	CAP FXD MICA 270 PFD		
C616	..27512-0271	CAP FXD MICA 270 PFD		
E101	610-0093	TERMINAL SOLDER		
E102	610-0093	TERMINAL SOLDER		
E103	610-0093	TERMINAL SOLDER		
E104	610-0093	TERMINAL SOLDER		
E106	610-0093	TERMINAL SOLDER		
E107	610-0093	TERMINAL SOLDER		
E108	610-0093	TERMINAL SOLDER		
E201	610-0093	TERMINAL SOLDER		
E301	610-0093	TERMINAL SOLDER		
E302	610-0093	TERMINAL SOLDER		
L401	...3422-0222	INDUCTOR 2200 UH		
L601	...3422-0222	INDUCTOR 2200 UH		
L602	...3422-0332	INDUCTOR 3300 UH		
L603	...3422-0681	INDUCTOR 680 UH		
L604	...3422-0222	INDUCTOR 2200 UH		
Q 1	900-5246	TSTR 2N5246		
Q 1	...3431-0023	TSTR TI TIS 58		
Q101	900-3904	TSTR 2N3904		
Q201	900-3904	TSTR 2N3904		
Q301	900-3904	TSTR 2N3904		
Q302	900-5246	TSTR 2N5246		
Q302	...3431-0023	TSTR TI TIS 58		
Q303	900-5246	TSTR 2N5246		
Q303	...3431-0023	TSTR TI TIS 58		
Q304	900-3904	TSTR 2N3904		
Q305	900-3904	TSTR 2N3904		
Q306	900-3904	TSTR 2N3904		
Q401	...3431-0025	TSTR MOT MPS404A		
Q402	900-3904	TSTR 2N3904		
Q403	900-3904	TSTR 2N3904		
Q404	900-5246	TSTR 2N5246		
Q404	...3431-0023	TSTR TI TIS 58		
Q601	900-3904	TSTR 2N3904		
Q602	900-3904	TSTR 2N3904		
Q603	900-5246	TSTR 2N5246		
Q603	...3431-0023	TSTR TI TIS 58		
R 1	204-0103	RES FXD COMP 10.0 K		
R 2	204-0334	RES FXD COMP 330. K		
R 3	204-0105	RES FXD COMP 1.00 MEG		
R 4	204-0105	RES FXD COMP 1.00 MEG		
R 5	204-0104	RES FXD COMP 100. K		
R 6	212-5360	RES FXD FILM 536 OHM		
R 7	212-2053	RES FXD FILM 205. K		
R 8	204-0473	RES FXD COMP 47.0 K		
R 9	204-0473	RES FXD COMP 47.0 K		
R 10	204-0104	RES FXD COMP 100. K		
R 11	204-0473	RES FXD COMP 47.0 K		
R 12	204-0105	RES FXD COMP 1.00 MEG		
R 13	204-0105	RES FXD COMP 1.00 MEG		
R 14	204-0205	RES FXD COMP 2.00 MEG		
R 15	204-0334	RES FXD COMP 330. K		
R 16	204-0105	RES FXD COMP 1.00 MEG		
R 17	204-0105	RES FXD COMP 1.00 MEG		
R 18	204-0104	RES FXD COMP 100. K		
R 19	204-0514	RES FXD COMP 510. K		
R 20	204-0103	RES FXD COMP 10.0 K		
R 21	204-0102	RES FXD COMP 1.00 K		
R101	204-0472	RES FXD COMP 4.70 K		
R102	204-0102	RES FXD COMP 1.00 K		
R103	204-0102	RES FXD COMP 1.00 K		
R104	...4567-0013	RES VAR COMP 5K		
R105	204-0103	RES FXD COMP 10.0 K		
R106	204-0103	RES FXD COMP 10.0 K		
R107	203-0100	RES FXD COMP 10.0 OHM		
R108	203-0150	RES FXD COMP 15 OHM		
R109	204-9561	RES FXD COMP 5.6 OHM		
R110	204-9821	RES FXD COMP 8.2 OHM		
R111	204-0102	RES FXD COMP 1.00 K		
R112	204-0680	RES FXD COMP 68 OHM		
R113	204-0473	RES FXD COMP 47.0 K		
R201	204-0100	RES FXD COMP 10.0 OHM		
R202	204-0102	RES FXD COMP 1.00 K		
R203	204-0102	RES FXD COMP 1.00 K		

SPL02C MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	T F E M E T R I C S STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
R204	204-0362	RES FXD COMP 3.6 K		
R205	204-0102	RES FXD COMP 1.00 K		
R206	204-0104	RES FXD COMP 100. K		
R207	204-0162	RES FXD COMP 1.60 K		
R208	204-0162	RES FXD COMP 1.60 K		
R209	204-0100	RES FXD COMP 10.0 OHM		
R210	204-0270	RES FXD COMP 27.0 OHM		
R213	204-9511	RES FXD COMP 5.1 OHM		
R301	204-0121	RES FXD COMP 120. OHM		
R302	204-0472	RES FXD COMP 4.70 K		
R303	204-0223	RES FXD COMP 22.0 K		
R304	204-0472	RES FXD COMP 4.70 K		
R305	204-0473	RES FXD COMP 47.0 K		
R306	204-0473	RES FXD COMP 47.0 K		
R307	204-0391	RES FXD COMP 390. OHM		
R308	204-0103	RES FXD COMP 10.0 K		
R309	204-0472	RES FXD COMP 4.70 K		
R310	204-0472	RES FXD COMP 4.70 K		
R311	204-0514	RES FXD COMP 510. K		
R312	204-0394	RES FXD COMP 390 K		
R313	204-0106	RES FXD COMP 10.0 MEG		
R314	204-0472	RES FXD COMP 4.70 K		
R315	204-0102	RES FXD COMP 1.00 K		
R316	204-0102	RES FXD COMP 1.00 K		
R317	204-0514	RES FXD COMP 510. K		
R318	204-0105	RES FXD COMP 1.00 MEG		
R319	204-0106	RES FXD COMP 10.0 MEG		
R320	204-0472	RES FXD COMP 4.70 K		
R321	204-0102	RES FXD COMP 1.00 K		
R322	204-0102	RES FXD COMP 1.00 K		
R323	204-0103	RES FXD COMP 10.0 K		
R401	204-0563	RES FXD COMP 56.0 K		
R402	204-0223	RES FXD COMP 22.0 K		
R403	204-0105	RES FXD COMP 1.00 MEG		
R404	204-0205	RES FXD COMP 2.00 MEG		
R405	204-0223	RES FXD COMP 22.0 K		
R406	204-0105	RES FXD COMP 1.00 MEG		
R407	204-0245	RES FXD COMP 2.4 MEG		
R408	204-0473	RES FXD COMP 47.0 K		
R409	204-0103	RES FXD COMP 10.0 K		
R410	204-0332	RES FXD COMP 3.30 K		
R411	204-0102	RES FXD COMP 1.00 K		
R412	204-0473	RES FXD COMP 47.0 K		
R413	204-0105	RES FXD COMP 1.00 MEG		
R414	204-0205	RES FXD COMP 2.00 MEG		
R415	204-0224	RES FXD COMP 220. K		
R416	..76278-0005	RES VARIABLE 50K		
R417	204-0104	RES FXD COMP 100. K		
R418	204-0105	RES FXD COMP 1.00 MEG		
R419	204-0205	RES FXD COMP 2.00 MEG		
R420	204-0104	RES FXD COMP 100. K		
R421	204-0105	RES FXD COMP 1.00 MEG		
R422	204-0205	RES FXD COMP 2.00 MEG		
R423	212-8060	RES FXD FILM 806 OHM		
R424	212-3163	RES FXD FILM 316. K		
R425	212-6343	RES FXD FILM 634 K		
R426	204-0224	RES FXD COMP 220. K		
R427	204-0105	RES FXD COMP 1.00 MEG		
R428	204-0205	RES FXD COMP 2.00 MEG		
R429	204-0104	RES FXD COMP 100. K		
R430	204-0104	RES FXD COMP 100. K		
R431	204-0103	RES FXD COMP 10.0 K		
R432	204-0224	RES FXD COMP 220. K		
R433	204-0105	RES FXD COMP 1.00 MEG		
R434	204-0205	RES FXD COMP 2.00 MEG		
R435	204-0102	RES FXD COMP 1.00 K		
R436	204-0222	RES FXD COMP 2.20 K		
R437	204-0223	RES FXD COMP 22.0 K		
R438	204-0223	RES FXD COMP 22.0 K		
R440	204-0103	RES FXD COMP 10.0 K		
R441	204-0820	RES FXD COMP 82 OHM		
R442	204-0102	RES FXD COMP 1.00 K		
R444	204-0334	RES FXD COMP 330. K		
R445	204-0222	RES FXD COMP 2.20 K		
R446	202-0101	RES FXD COMP 100. OHM		
R447	204-0332	RES FXD COMP 3.30 K		
R601	204-0471	RES FXD COMP 470. OHM		
R602	204-0222	RES FXD COMP 2.20 K		
R603	204-0102	RES FXD COMP 1.00 K		
R604	204-0682	RES FXD COMP 6.80 K		
R605	204-0222	RES FXD COMP 2.20 K		
R606	204-0102	RES FXD COMP 1.00 K		
R607	204-0220	RES FXD COMP 22 OHM		
R608	204-0681	RES FXD COMP 680. OHM		
R609	204-0222	RES FXD COMP 2.20 K		

SPL020 MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	T P E M C T R I C S STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
R610	204-0330	RES FXD COMP 33.0 OHM		
R611	204-0102	RES FXD COMP 1.00 K		
R612	204-0222	RES FXD COMP 2.20 K		
R613	204-0332	RES FXD COMP 3.30 K		
R614	204-0223	RES FXD COMP 22.0 K		
R615	204-0102	RES FXD COMP 1.00 K		
R616	204-0332	RES FXD COMP 3.30 K		
R617	212-1052	RES FXD FILM 10.5K		
R618	212-1052	RES FXD FILM 10.5K		
R619	212-5111	RES FXD FILM 5.11 K		
R620	204-0103	RES FXD COMP 10.0 K		
R621	204-0471	RES FXD COMP 470. OHM		
S 1	..24690-0201	SWITCH TOGGLE DPDT		
S 2	..24690-0301	SWITCH,TOGGLE 3PDT		
S101	..76340-0010	SWITCH TOGGLE		
S102	..76340-0010	SWITCH TOGGLE		
S201	..24690-0101	SWITCH TOGGLE SPDT		
S202	..24690-0101	SWITCH TOGGLE SPDT		
S203	..24690-0101	SWITCH TOGGLE SPDT		
S204	..24690-0101	SWITCH TOGGLE SPDT		
S205	..24690-0101	SWITCH TOGGLE SPDT		
S206	..24690-0101	SWITCH TOGGLE SPDT		
S207	..24690-0101	SWITCH TOGGLE SPDT		
S208	..24690-0101	SWITCH TOGGLE SPDT		
S601	..24690-0101	SWITCH TOGGLE SPDT		
U 1	..24201-0090	IC SN7490N		
U 2	..76387-0004	IC LM3900N QUAD AMP		
U101	..24201-0090	IC SN7490N		
U102	..24201-0090	IC SN7490N		
U103	..24201-0090	IC SN7490N		
U104	..24201-0090	IC SN7490N		
U105	..24201-7400	IC SN7400N		
U106	..24201-0002	IC SN7402N		
U107	..24201-0073	IC SN7473N		
U108	..24201-0090	IC SN7490N		
U109	..24201-0090	IC SN7490N		
U110	..24201-0121	IC SN74121N		
U111	..24201-0121	IC SN74121N		
U112	..24201-0002	IC SN7402N		
U113	..24201-7400	IC SN7400N		
U114	..24201-0121	IC SN74121N		
U115	..76385-0004	IC UGH7806-393 6V REG		
U201	..24344-0001	IC MC4044P		
U202	..24345-0001	IC MC4024P		
U203	..24201-7400	IC SN7400N		
U204	..24201-0090	IC SN7490N		
U205	..24201-0193	IC SN74193N		
U206	..24201-0193	IC SN74193N		
U301	..76387-0006	IC LM309H		
U302	..76387-0001	IC LM301AN		
U303	..76387-0004	IC LM3900N QUAD AMP		
U401	..76387-0004	IC LM3900N QUAD AMP		
U402	..76387-0004	IC LM3900N QUAD AMP		
U403	..76387-0004	IC LM3900N QUAD AMP		
CR401	800-0914	DIODE 1N914		
CR402	800-0914	DIODE 1N914		
CR403	800-0914	DIODE 1N914		
CR404	800-0914	DIODE 1N914		
DS 1	..76434-0005	LED HI INTENSITY GRN		
RT401	..76457-0001	THERMISTOR 10K		
TP101	610-0093	TERMINAL SOLDER		
TP102	610-0093	TERMINAL SOLDER		
TP104	610-0093	TERMINAL SOLDER		
TP105	610-0093	TERMINAL SOLDER		
TP106	610-0093	TERMINAL SOLDER		
TP107	610-0093	TERMINAL SOLDER		
TP108	610-0093	TERMINAL SOLDER		
TP110	610-0093	TERMINAL SOLDER		
TP201	610-0093	TERMINAL SOLDER		
TP202	610-0093	TERMINAL SOLDER		
TP301	610-0093	TERMINAL SOLDER		
TP302	610-0093	TERMINAL SOLDER		
TP401	610-0093	TERMINAL SOLDER		
TP402	610-0093	TERMINAL SOLDER		
TP403	610-0093	TERMINAL SOLDER		
TP404	610-0093	TERMINAL SOLDER		
TP405	610-0093	TERMINAL SOLDER		
TP406	610-0093	TERMINAL SOLDER		

* * * * ASSEMBLY NO ..19348-0001 PCB ASSY ANT COUPLER * * * *

1	..19305	PCB ANTENNA COUPLER
9	82	INSULATOR TSTR PAD
31	..19358	DIA SCH ANT COUPLER

SPL020 MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	T P E M E T R I C S STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
C 1	...3321-9102	CAP FXD CER .1 MFD		
C 2	...3321-9102	CAP FXD CER .1 MFD		
C 3	...8914-0100	CAP FXD TA 10 MFD		
C 4	...8914-0100	CAP FXD TA 10 MFD		
C 5	...8914-0470	CAP FXD TA 47 MFD		
C 6	..21485-9101	CAP FXD TA 1 MFD		
C 7	..27512-0101	CAP FXD MICA 100 PFD		
C 8	..27512-0101	CAP FXD MICA 100 PFD		
C 9	..27512-0102	CAP FXD MICA 1000 PFD		
C 10	..27512-0102	CAP FXD MICA 1000 PFD		
C 11	..27512-0100	CAP FXD MICA 10 PFD		
C 12	..27512-0100	CAP FXD MICA 10 PFD		
E 1	610-0093	TERMINAL SOLDER		
E 2	610-0093	TERMINAL SOLDER		
E 3	610-0093	TERMINAL SOLDER		
E 4	610-0093	TERMINAL SOLDER		
E 5	610-0093	TERMINAL SOLDER		
E 6	..18678-0001	PROTECT SURGE VOLTAGE		
Q 1	901-4221	TSTR 2N4221A		
Q 2	900-2905	TSTR 2N2905		
Q 3	900-2270	TSTR 2N2270		
Q 4	900-2270	TSTR 2N2270		
R 1	201-0101	RES FXD COMP 100. OHM		
R 2	204-0102	RES FXD COMP 1.00 K		
R 3	204-0103	RES FXD COMP 10.0 K		
R 4	204-0395	RES FXD COMP 3.9 MEG		
R 5	204-0151	RES FXD COMP 150. OHM		
R 6	204-0153	RES FXD COMP 15.0 K		
R 7	204-0332	RES FXD COMP 3.30 K		
R 8	204-0152	RES FXD COMP 1.50 K		
R 9	204-0222	RES FXD COMP 2.20 K		
R 10	204-0271	RES FXD COMP 270. OHM		
R 11	204-0271	RES FXD COMP 270. OHM		
R 12	204-0154	RES FXD COMP 150. K		
R 13	204-0275	RES FXD COMP 2.70 MEG		
R 14	204-0471	RES FXD COMP 470. OHM		
R 15	204-0472	RES FXD COMP 4.70 K		
R 16	204-0472	RES FXD COMP 4.70 K		
R 17	204-0472	RES FXD COMP 4.70 K		
R 18	204-0224	RES FXD COMP 220. K		
R 19	204-0332	RES FXD COMP 3.30 K		
R 20	204-0395	RES FXD COMP 3.9 MEG		
CR 1	800-0914	DIODE 1N914		
CR 2	800-0914	DIODE 1N914		

* * * * ASSEMBLY NO ..19350-0001 900A VLF/LF RCVR 115V * * * *

1	..19350-9999	ASSY 900A OPTS/PARTS
6	...3388-0092	CABLE COAX RG-178B/U
12	...5050-0048	STANDOFF HEX 4-40X3/4
13	..19272-0001	PANEL FRONT RCVR
14	..19308-0001	PCB ASSY RECEIVER
15	..19344-0001	SCALE RECORDER
16	..19349-0001	PLATE FREQ
17	..19351-0001	BRACKET RECORDER
18	..19352-0001	COVER ASSY RCVR
19	..19353-0001	ACC KIT ASSY RCVR
21	..19356	DIA SCH PS/INTERCONN
23	.599287-0012	RECORDER
27	...4161-0028	KNOB PLAIN DEC SKIRT
28	...6152-0001	PLATE ID INSTR STD
28	..79603	DIA SCH 900 J/K MSK

* * * * ASSEMBLY NO ..19350-0002 900A VLF/LF RCVR 230V * * * *

1	..19350-0001	900A VLF/LF RCVR 115V
3	..19356	DIA SCH PS/INTERCONN
6	.599287-0014	RECORDER
8	...6152-0001	PLATE ID INSTR STD
9	..19350-9999	ASSY 900A OPTS/PARTS
F501	...3487-9502	FUSE 1/2 A 250 VOLT

* * * * ASSEMBLY NO ..19350-0003 900A VLF/LF RCVR 115V * * * *

1	..19350-9999	ASSY 900A OPTS/PARTS
6	...3388-0092	CABLE COAX RG-178B/U
12	...5050-0048	STANDOFF HEX 4-40X3/4
13	..19272-0001	PANEL FRONT RCVR
14	..19308-0001	PCB ASSY RECEIVER
15	..19344-0001	SCALE RECORDER
16	..19349-0001	PLATE FREQ
17	..19351-0001	BRACKET RECORDER

SPLC2C MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	T E M E T R I C S STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
18	..19352-0001	COVER ASSY RCVR		
19	..19353-0001	ACC KIT ASSY RCVR		
21	..19356	DIA SCH PS/INTERCONN		
27	...4161-0028	KNOB PLAIN DEC SKIRT		
28	...6152-0001	PLATE ID INSTR STD		
28	..79603	DIA SCH 900 J/K MSK		
29	..18146-0001	COVER		

• • • • ASSEMBLY NO ..19350-0004 900A VLF/LF RCVR 230V • • • •

1	..19350-0001	900A VLF/LF RCVR 115V
3	..19356	DIA SCH PS/INTERCONN
6	..19350-9999	ASSY 900A OPTS/PARTS
8	...6152-0001	PLATE ID INSTR STD
10	..18146-0001	COVER
F501	...3487-9502	FUSE 1/2 A 250 VOLT

• • • • ASSEMBLY NO ..19352-0001 COVER ASSY RCVR • • • •

1	..19284-0001	COVER,REAR-RCVR
17	...3426-0022	TUBING INSULATING
22	...3624-0005	LUG SOLDER NO 6
23	...3486-0027	LUG TERMINAL 3/8
25	...3794-0003	INSULATOR MICA
33	...4301-0005	COMPOUND SI HT TRANS
34	...4492-0011	WSHR SHOULDER NO 6
38	..23969-0529	CLIP
40	..32115-0061	CLAMP CABLE
42	...4660-0005	TERM RING #10 22-16
45	..19356	DIA SCH PS/INTERCONN
48	..19670-0006	BRACE,XFMR
C501	...3403-9503	CAP FXD CER .05 UF
C502	...3322-9102	CAP FXD CER .1 MFD
C503	..23969-0005	CAPACITOR 3900 MFD
F501	...3487-9752	FUSE 3/4 A 250 VOLT
J 1	...3391-0002	CONN BNC FEMALE
J 2	...3391-0002	CONN BNC FEMALE
P501	...3648-0008	CONN SOC ELEC
R501	..76456-0006	RES FXD PWR 7.5 OHM
R502	..76456-0006	RES FXD PWR 7.5 OHM
R503	..76456-0006	RES FXD PWR 7.5 OHM
R504	212-3570	RES FXD FILM 357 OHM
R505	212-3320	RES FXD FILM 332 OHM
R506	204-0000	RES FXD COMP SEL VAL
S501	..24690-7201	SWITCH TOGGLE
T501	..76367-0001	TRANSFORMER 12/24 V
U501	..24142-0001	IC LM309K
W501	...3467-0028	CABLE 3-CONDUCTOR
CR501	800-4002	DIODE 1N4002
CR502	800-4002	DIODE 1N4002
CR503	800-4002	DIODE 1N4002
CR504	800-4002	DIODE 1N4002
CR506	800-4002	DIODE 1N4002
TP501	...3613-0037	TERMINAL STRIP 5 PIN
TP502	...3613-0037	TERMINAL STRIP 5 PIN
TP503	...3613-0040	TERMINAL STRIP
TP504	...3613-0040	TERMINAL STRIP
TP505	...4344-0001	CONNECTOR TIP JACK
XF501	...3769-0002	HOLDER FUSE

• • • • ASSEMBLY NO ..19353-0001 ACC KIT ASSY RCVR • • • •

1	...3487-9752	FUSE 3/4 A 250 VOLT
2	...3650-0001	PAPER CHART ROLL
3	...4274-0002	ANTENNA WHIP 48" LTH
4	..19354-0001	ANTENNA COUPLER ASSY
5	..79611	MANUAL OPS-SVC 900A
6	..76304-1918	LAMP MINATURE 18V
7	.599168	ASSY ANTENNA CABLE
8	.599665	MANUAL RUSTRAK RCDR

• • • • ASSEMBLY NO ..19354-0001 ANTENNA COUPLER ASSY • • • •

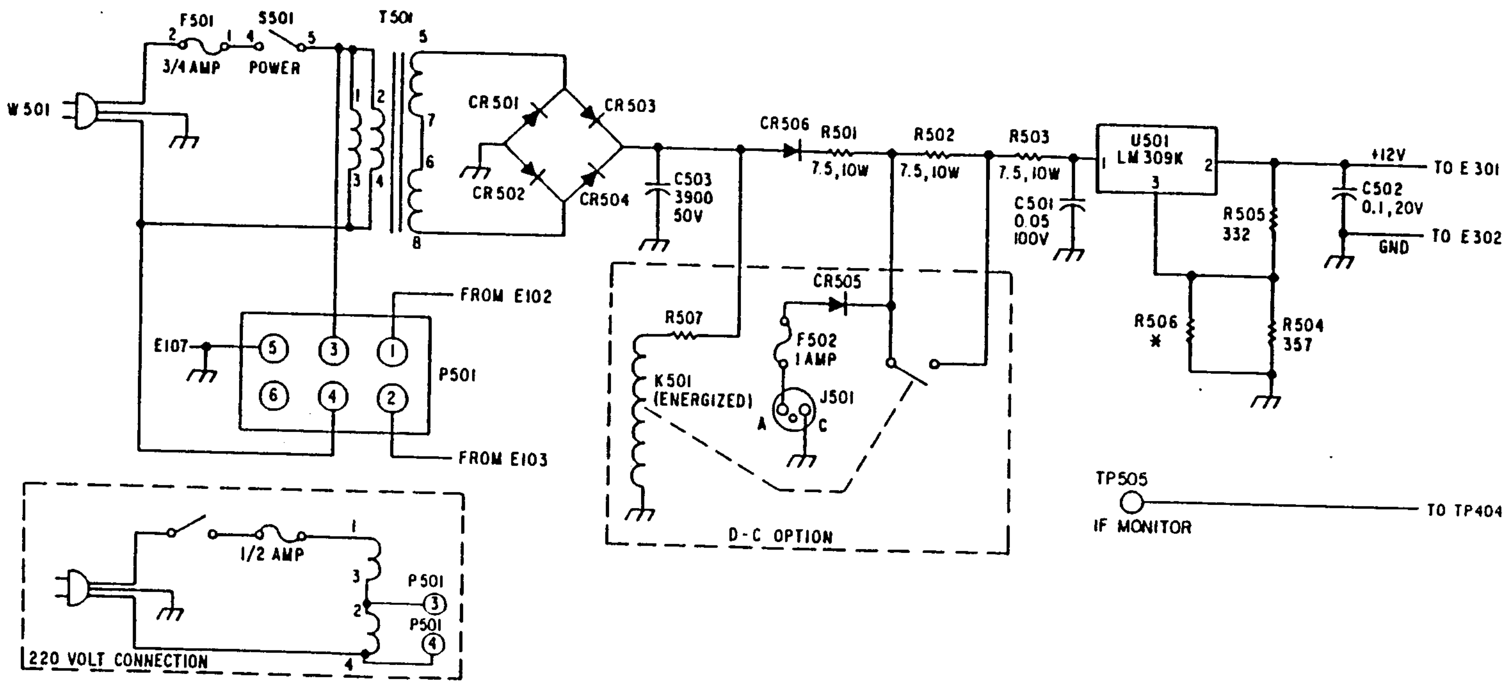
2	649-0193	NUT HEX 1/4-20
5	...3624-0014	LUG SOLDER NO 10
6	...3624-0021	LUG SOLDER 1/4
8	...4189-0030	WASHER FLAT 1/4
10	...4243-0048	SCR PHD 1/4-20 X 3/4
12	...4343-0013	ADHESIVE GEN PURPOSE
13	...4368-0001	SCR SLFSE 4-40X1/4
15	...5046-0156	STANDOFF H 4-40X1 7/8

SPL020 MANUAL PARTS LIST AS OF 10/30/90

REFERENCE DESIGNATION	THEMSTRICS STOCK NUMBER	DESCRIPTION	TYPICAL MFGR	MANUFACTURER PART NUMBER
16	..18196-0001	BOX MODIFIED		
17	..18197-0002	COVER, MODIFIED		
18	..19268-0001	BUSHING ANTENNA RND		
19	..19348-0001	PCB ASSY ANT COUPLER		
20	..19358	DIA SCH ANT COUPLER		
22	..23454-0004	INSULATOR THRU-PANEL		
23	..76301-0002	SEALANT ADH SWS-960		
24	..23996-0002	PRIMER		
26	...3486-0027	LUG TERMINAL 3/8		
27	..23695-0023	SCR SET HEX SOC 6-32		
28	...6152-0001	PLATE ID INSTR STD		
29	608-0004	ROD CONT THD 10-32		
J 1	...3391-0002	CONN BNC FEMALE		

• • • • ASSEMBLY NO .599168 ASSY ANTENNA CABLE • • • •

1	...3388-0028	CABLE COAX RG-58C/U		
2	...4196-0001	CONN COAX RF CABLE		

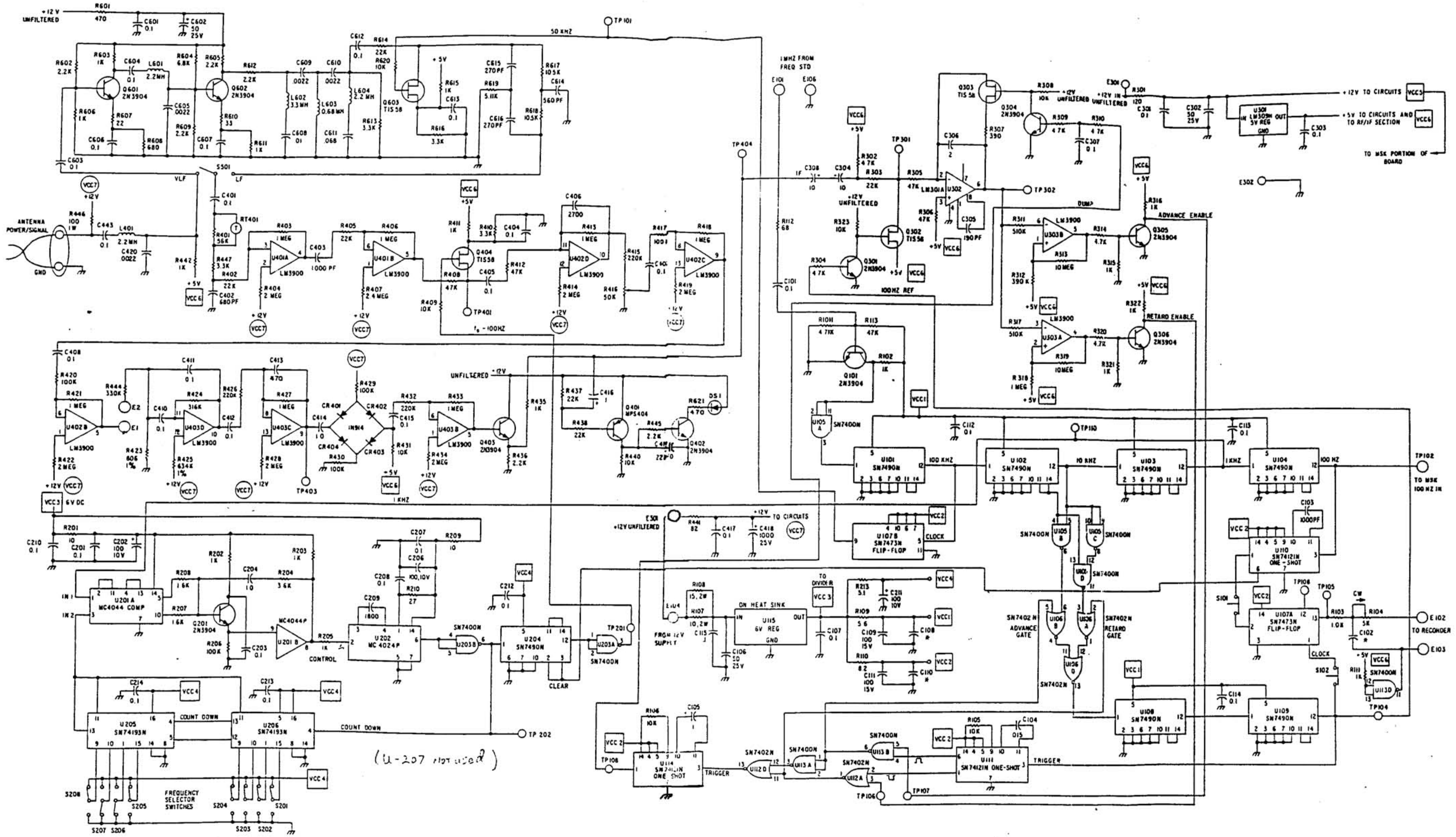


* 3. SELECTED FOR 12V OUT OF U501
2. ALL CR'S ARE IN4002
1. ALL RESISTORS ARE 1/4 W ± 5% TOL WITH VALUES IN OHMS; CAPACITOR VALUES ARE IN MICROFARADS

NOTES UNLESS OTHERWISE SPECIFIED

Diagram Schematic, Chassis, Drawing No. 19356E

79611



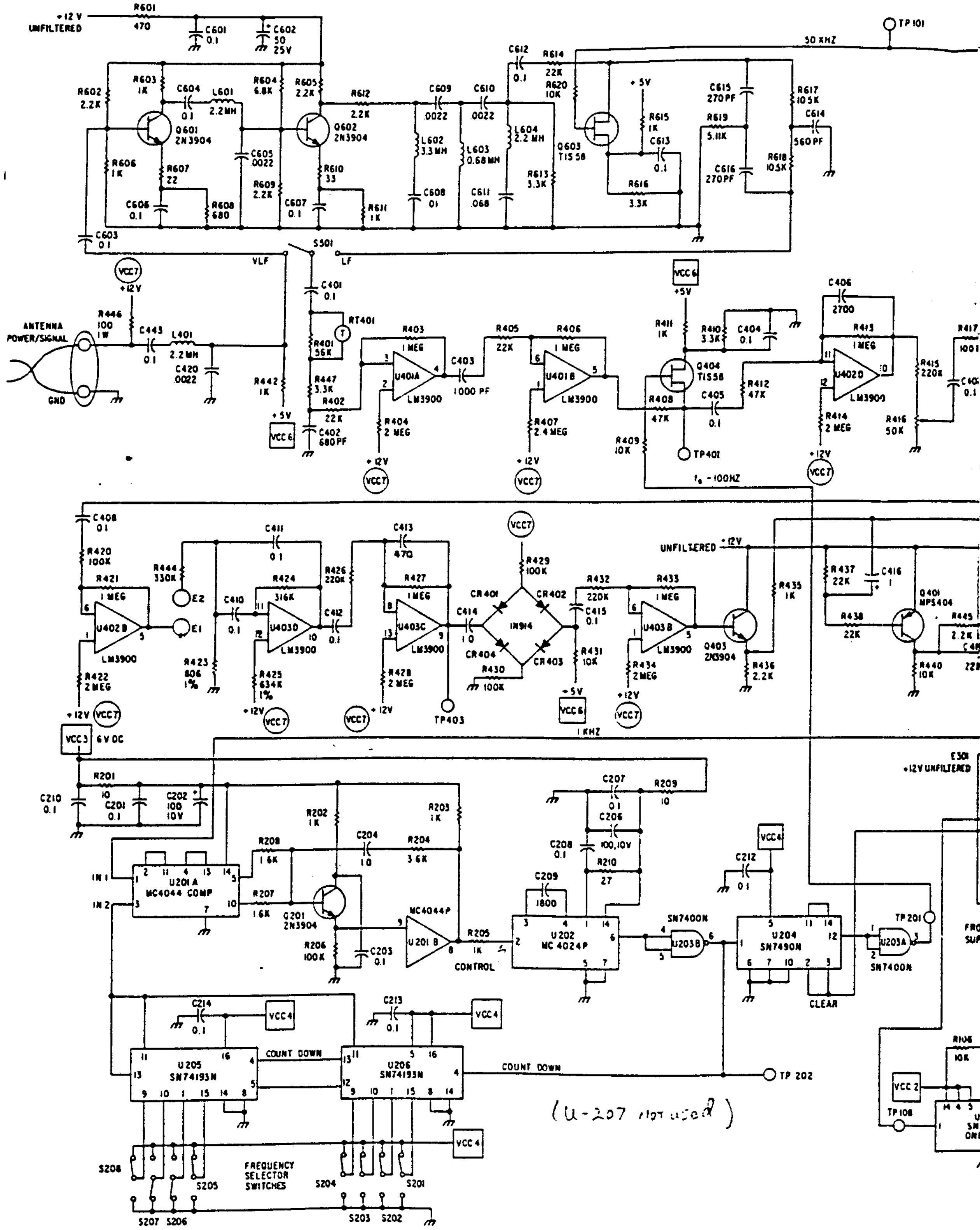
NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE 1/4 W ±5% TOL WITH VALUES IN OHMS; CAPACITOR VALUES ARE IN MICROFARADS
* 2. NOT NORMALLY USED
3. TIS-58 MAY BE REPLACED WITH 2N5246, OBSERVE BASING

TIS-58 FLAT SGD

2N5246 FLAT GSD

Diagram Schematic, Receiver PCB, Drawing No. 19357?



3. TIS-58 MAY BE REPLACED WITH 2N5246, OBSERVE BASING

TIS-58 FLAT SGD

2N5246 FLAT GSD

* 2. NOT NORMALLY USED

1. ALL RESISTORS ARE 1/4 W ±5% TOL WITH VALUES IN OHMS; CAPACITOR VALUES ARE IN MICROFARADS

NOTES: UNLESS OTHERWISE SPECIFIED

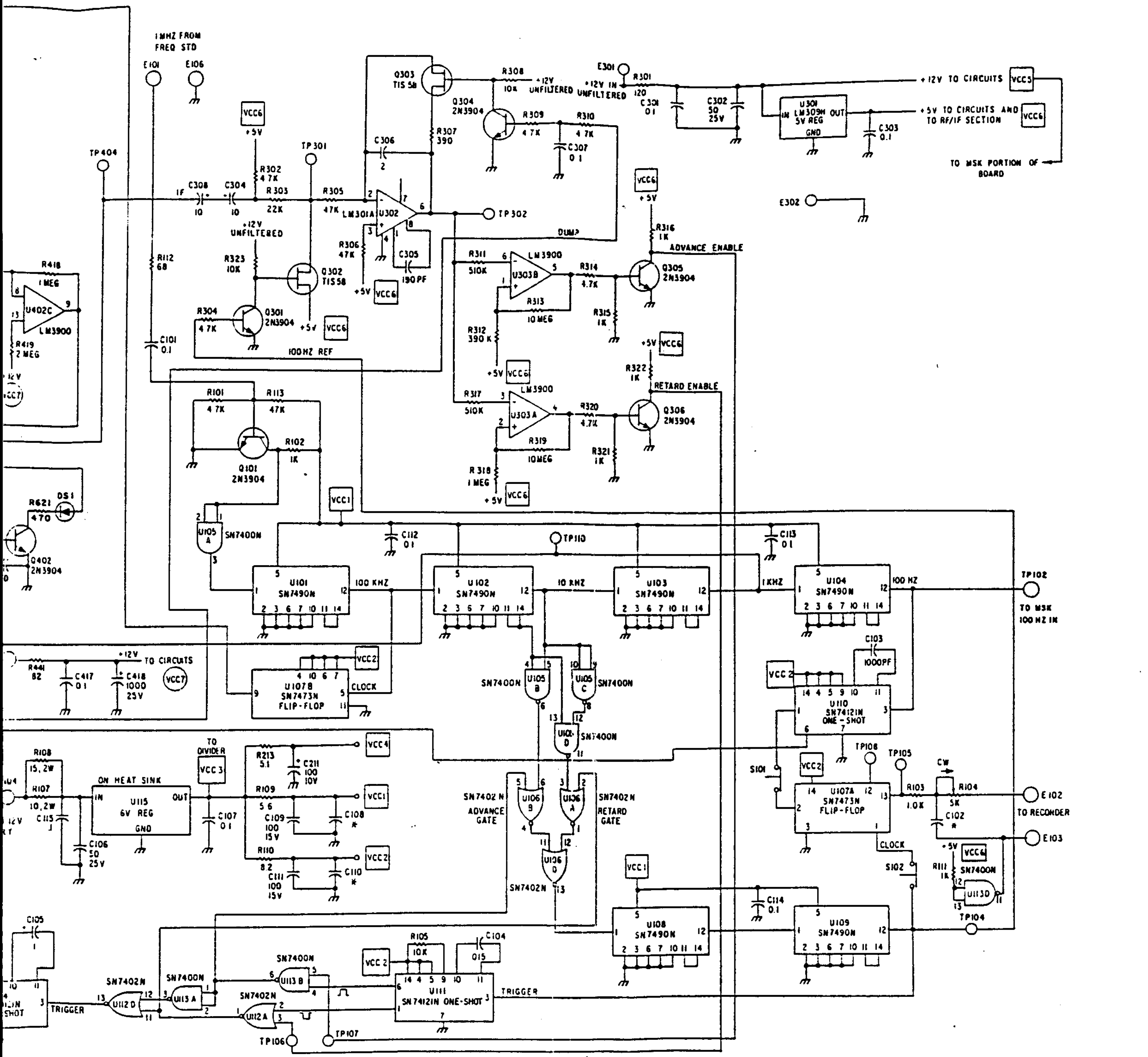
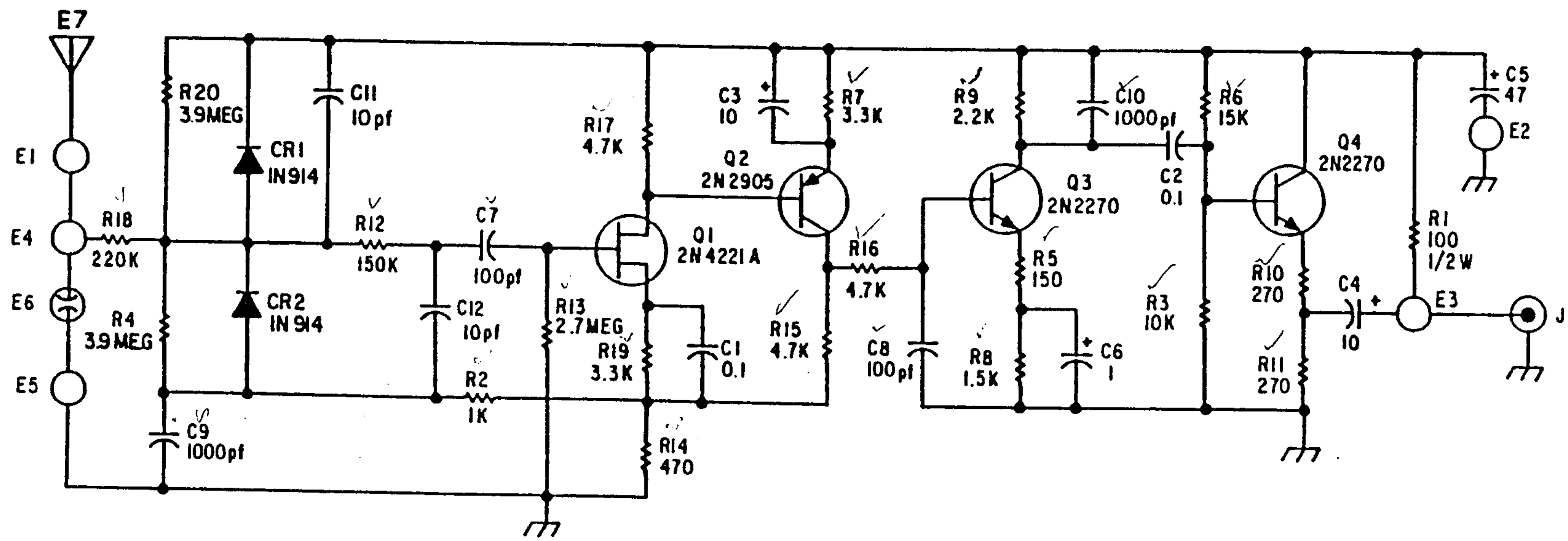


Diagram Schematic, Receiver PCB, Drawing No. 19357



1. ALL RESISTORS ARE 1/4 W ± 5% TOL WITH VALUES IN OHMS;
CAPACITOR VALUES ARE IN MICROFARADS

NOTES: UNLESS OTHERWISE SPECIFIED

Diagram Schematic, Antenna Coupler, Drawing No. 19358C

(Active Antenna)

Receives D.C. Power thru Coax From Receive

79611